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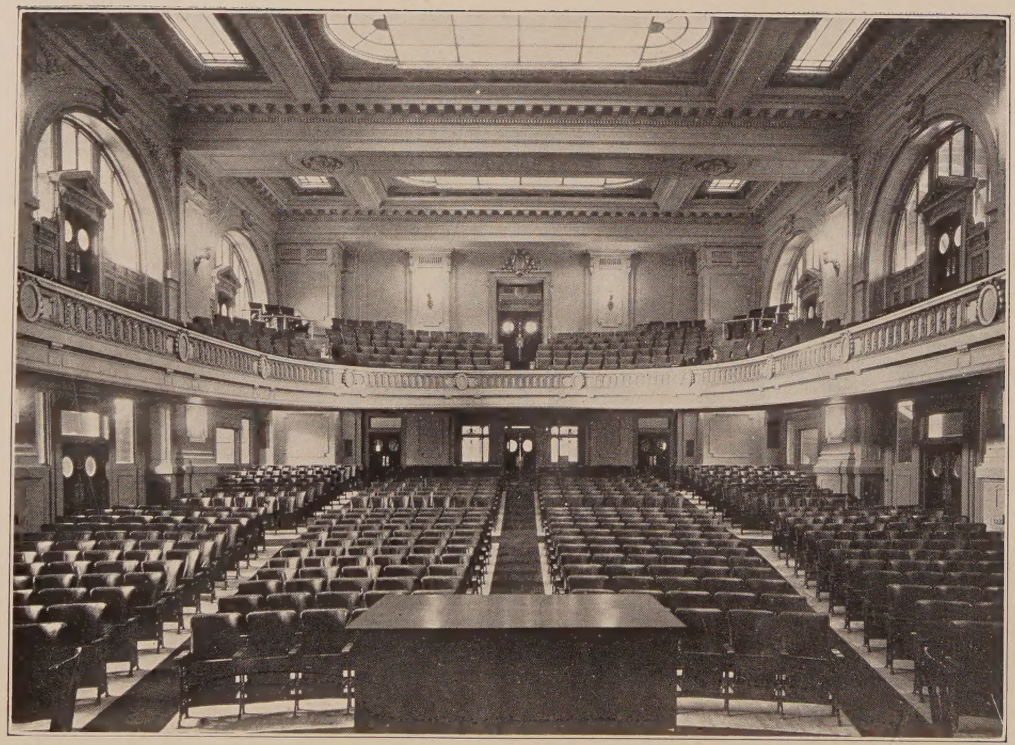

AUDIENCE ROOM ENGINEERING SOCIETIES' BUILDING, NEW YORK.

PRACTICAL ILLUMINATION

BY

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AND

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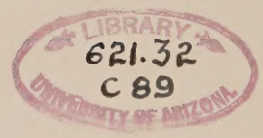

PREFACE.

It is a matter of common knowledge among experts that a large amount of the artificial light that is now being produced is unnecessarily lost. Cases where this loss reaches one-half or two-thirds are matters of common observation. This does not include the waste of light by users who forget to turn it off when not needed. It refers simply to the failure of the average user to get anywhere near the full benefit possible from the light produced. Even more important than the economical side of the subject is the disastrous effect on the eyes caused by numerous common artificial lighting arrangements.

The broad general principles which should be followed in the design of artificial illumination have been already well laid down by eminent authorities. The present work has been undertaken by the authors in order to supply much needed specific data and suggestions as to how to carry out these principles in practice.

This common failure to get the practical results that should be obtained from the light purchased, as well as much of the ruin of eyesight now common with artificial light, is due to the fact that so few people understand the importance of the proper placing, reflecting and shading of artificial lights. More attention is being paid to these things than formerly, as is evidenced by the recent formation of the Illuminating Engineering Society; but there is still a great lack of easily available information on the many practical and technical points involved in the use of artificial light.

In what follows, the authors attempt to present exact practical information of every-day use on many points that come up in arranging artificial lighting. Most of the information is in such shape that, while being of value to the technical man, it can be read with profit and applied by the non-technical public as well. A spreading of this kind of knowledge is to the interests both of electric light and gas companies and the users of such light.

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No attempt has been made to treat of the apparatus for production of light, but rather to confine the work to the much neglected subject of how best to use the light after it is produced.

A large number of tests are shown giving information on the light distribution of various illuminants with different globes, reflectors, and shades. Most of this information has not before been available to the general user. All of the tests in the book with the exception of a few which are noted in the text, were made by the Electrical Testing Laboratories of New York City. They have thus the advantage of being from a uniform, unbiased source, this source being a laboratory which has behind it long experience and an established reputation in this class of work. No tests made by manufacturers have been used.

Interior illumination only has been taken up, no attempt being made to deal with the important but much neglected subject of scientific street lighting.

Since it is in many cases of practical convenience or importance to know the exact make and trade designation of articles tested, an Appendix has been prepared in which opposite the Fig. number of each test will be found the manufacturer, name and trade number or designation of the article tested.

Part 2 is largely given to illustrations of rooms of various kinds with good and bad lighting arrangements. Their desirable and undesirable features are discussed. The method of treatment here as in the rest of the book has been to illustrate principles first by specific practical examples and then from these to point general conclusions.

CONTENTS.

Chapter		Page
I.	Introduction	1
II.	The Laws and Measurement of Light	3
III.	Light and the Eye	9
IV.	Calculation of Illumination	13
V.	Individual Incandescent Electric Lamps and Their Reflectors, Shades and Globes	25
VI.	Individual Gas Burners and Their Reflectors, Shades and Globes	76
VII.	Acetylene Gas Burners and Their Shades	96
VIII.	Incandescent Electric Lamp Clusters and Bowls	101
IX.	Nernst Lamps and Their Globes	115
X.	Electric Arc Lamps	120
XI.	Gas Arc Lamps	128
XII.	Vapor Lamps	134
XIII.	Demonstration Room Tests	136
XIV.	Comparison of Illuminants	142
XV.	Introduction to Practical Examples	147
XVI.	Residence Lighting	151
XVII.	Desk, Drafting Room and Office Lighting	215
XVIII.	The Lighting of Public Halls and Lodge Rooms	227
XIX.	The Lighting of Large Dining and Banquet Rooms	232
XX.	The Lighting of Large Public Rooms, Depots, Lobbies, etc	241
XXI.	The Lighting of Hall and Corridors of Large Office Buildings	255
XXII.	The Lighting of Theaters	262
XXIII.	The Lighting of Churches	268
XXIV.	The Lighting of Libraries, Reading and School Rooms	280
XXV.	Car Lighting	288
XXVI.	Store Lighting	293
XXVII.	Show Window Lighting	324
XXVIII.	Shop and Factory Lighting	332
XXIX.	Miscellaneous Examples of Lighting	337
Appendix		346
Index		349

CHAPTER I.

INTRODUCTION.

Before going into the details of the various points involved in artificial lighting, a short statement of some of the principal reasons why present attempts at efficient illumination are so often found faulty will aid to an understanding of the subject.

One reason why much light is wasted is that frequently too much of the light goes in directions where it is not needed and too little in directions where it is needed. If light coming from a lamp were a tangible thing, as, for example, water coming from a hose, failure to direct it where needed would be more apparent than it is. No one would think of trying to wash windows, flush off pavements or do similar work calling for a concentrated stream of water with a hose fitted with a lawn sprinkler which throws a gentle spray in all directions. Nor would one think of using a nozzle giving a powerful stream on a flower bed or a soft, newly-made lawn. The light thrown in different directions around a lamp can be modified with globes and reflectors just as the direction and character of a stream of water issuing from a hose can be modified by the nozzle. The important point is to pick the right kind of nozzle and the right kind of reflector or globe for the particular work in hand. Although a certain amount of light on ceilings and walls is a good thing, it is quite likely to be the case that a much larger proportion of the total light goes in those directions than is at all necessary, while a smaller proportion than is necessary is thrown in places where it can be utilized. On the other hand, there are cases where the reverse of this is true.

It is of first importance to know what effects various reflectors, shades and globes will produce. Much attention is therefore given to this in following chapters.

Another common mistake in lighting is to place the lamps in the line of ordinary vision and to fail to cover them with dif-

fusing globes or shades so that the direct rays from the unshaded lamp fall directly into the eyes of the users or occupants of a room. This produces two effects which may not be realized. It is not only trying on the eyes but it is more difficult to see well with dazzling light in the line of vision than if the lamps were shaded or placed out of ordinary view. The rays of an intense light falling directly into the eyes cause the pupils to contract in self-defense, to cut down the light entering. The result is that so much light is shut out that objects in the room cannot be seen nearly as well and do not appear nearly as well lighted as if the intense source of light were kept out of the line of ordinary vision. We do not think of trying to look at the sun, as its temporary blinding effect is too pronounced and painful to make one wish to attempt it. The same effects, to a very much less degree, are produced when we look at intense artificial light such as that from the arc, the Nernst, the gas mantle burner or the incandescent lamp. The effect may be so small that it is not noticed at first, but is the cause of much unconscious straining of the eyes and reduces the practical value of the illumination of any room where bare arc, incandescent or gas lamps are not kept out of the ordinary line of vision. Such light shining in the eyes many hours a day in extreme cases causes an irritation that will produce partial blindness and enforce absolute rest. The remedy, of course, is to place the lamps high enough to avoid this if possible, and if that cannot be done, to protect the eyes by placing globes, shades, or reflectors on the lamps which will reduce the intensity without absorbing and wasting an undue amount of light. In this connection also the selection of proper globes and shades is important.

The position of the lamps is frequently not what it should be to get the best results. Some general rules about this can be laid down, but this phase of the subject can best be studied by pointing out the defects and good points of specific examples. Such examples will be given in Part 2 with the aid of numerous illustrations from photographs of rooms with lamps variously placed. Thus clearer ideas of the things to be sought and avoided can be obtained than by a study of abstract general principles.

CHAPTER II.

THE LAWS AND MEASUREMENT OF LIGHT.

It is desirable before considering practical examples of artificial lighting to consider some of the fundamental laws underlying the subject of light and the method of measuring the values of different illuminants whether with or without their globes, shades or reflectors. It is the intention here, for the sake of ready reference, to give only the fundamental laws in an extremely condensed form. Fuller discussions of such laws can be obtained from any text-book on physics or photometry.

From a purely physical standpoint, rapid vibrations of the ether striking the retina of the eye produce the sensation commonly known as light. Different rates of vibration produce different sensations which we distinguish as different colors; thus a low rate of vibration produces the color sensation of red while a higher rate of vibration produces the sensation of violet. Between these lie the other colors. Such vibrations of the ether, commonly known as rays, always travel in straight lines unless interfered with by some external cause. They may be changed in direction, however, as will be seen later in considering the questions of refraction and reflecti.n.

It is customary in this country to refer to all sources of light in terms of the light given in a horizontal direction by a standard candle.

Photometry.

A photometer is an instrument for measuring the light from any given source. All photometers are based on the law of inverse squares, *i.e.*, that the intensity of light varies inversely with the square of the distance from the source of light. Fig. 1 illustrates this graphically. It is evident from an inspection of this that the surface C, which is twice the distance of B from the source of light A, will have only one-fourth of the light rays falling on each point that fall on B, and that D will only have

one-ninth of that falling on B since the areas illuminated in both cases by the same rays are respectively four and nine times that of B.

Fig. 2 shows diagrammatically a Bunsen photometer. Briefly it consists of a standard source of light, A, the source of light to be measured, B, and a screen, S, which is composed of heavy white paper with a grease spot in the center. This is viewed

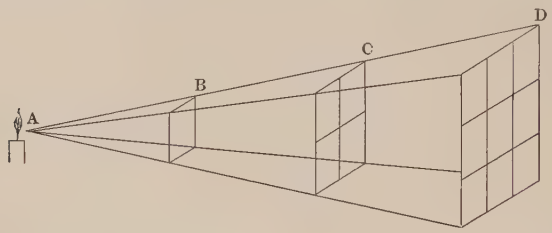


FIG. 1.— Illustrating Law of Inverse Squares.

from both sides at once by two mirrors M and N. When seen by reflected light the center will appear darker than the outside, since part of the light is transmitted and therefore less is reflected. If viewed by transmitted light, *i.e.*, light from the opposite, side the center will appear lighter than the outside, as the outside does not allow the light to pass through. In operation the screen is moved back and forth until the center spot is equally bright with the outside portion. By means of

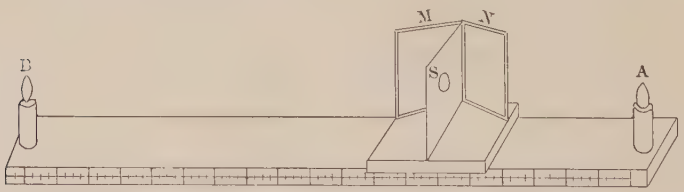


FIG. 2.— Showing principle of the photometer.

the two mirrors, placed at an angle, both sides of the screen can be seen at the same time and at the same angle. When they are equally bright the strengths of the two sources of light are inversely proportional to the squares of their distances from the screen. Thus if, when the screen is balanced as before explained, the distance from A to S is one foot, and from B to S four feet, light B will be sixteen times the strength of light A.

This would measure only the horizontal candle power. To get the candle power at other angles light *B* could be tipped, but in the case of measurements with a gas lamp and measurements of other sources of light where it is undesirable or inconvenient to tip them, there is actually employed in practice a series of mirrors which reflect the light at different angles into the photometer without necessitating the movement of the source of light.

Reflection.

It is customary to consider reflection as being of two different kinds, which while in themselves identical produce nevertheless entirely different results. Thus we have regular reflection in which a ray of light striking a reflecting surface, such as a mirror, is reflected as a sharp beam, the angle at which it strikes the mirror being equal to the angle at which it is reflected.

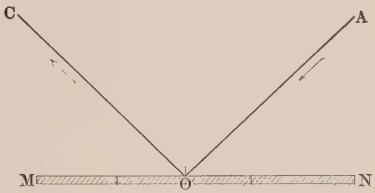


Fig. 3.— Illustrating regular reflection.

In Fig. 3, if *A O* be the beam of light striking *M N*, a reflecting surface, and *O C* is the reflected ray, the angles between the mirror *M N*, and such rays will be equal. That is to say the angle *A O N* equals the angle *C O M*. It will also be noted that the rays lie in the same plane. A common example of such reflection is that of an ordinary mirror. It should be noted in such cases that the reflecting surface, namely, the mirror, is not visible but only the object reflected. Such reflected rays are as a rule unchanged except in intensity and in some cases in color. The color as a rule varies with the nature of the reflecting surface. Thus burnished silver which has the highest reflecting power reflects 92 per cent. of the light thrown upon it while in the case of burnished copper the reflection falls to 50 per cent. or less and the rays are tinged with the color of the copper. As, however, we have to deal largely with mirrored surfaces such as for example mirrored troughs,

mirrored cone reflectors, etc., and as some of the ordinary forms of reflectors are made with such material it will be desirable to consider their case more in detail which will be done in the chapters on reflectors.

In the case of a rough surface, whether polished or unpolished, every individual ray of light striking such a surface is regularly reflected, but as each part of such surface lies at a different angle and in a different plane, the light is reflected in all directions. Thus in Fig. 4, we have a number of parallel rays of light striking on an irregular reflecting surface. It will be seen at once that while each ray is regularly reflected, the different rays of light are reflected in all directions and in different planes. This phenomenon is known as irregular or diffuse reflection. In some cases it will be noticed that the rays escape after a single reflection while in other cases the light is reflected

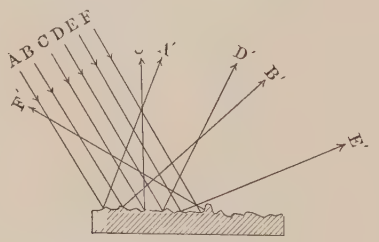


FIG. 4.—Illustrating irregular or diffuse reflection.

one or more times before escaping from such a surface. Diffuse reflection, therefore, scatters the rays in all directions, although in the case of certain materials such as glazed paper the larger number of rays will be regularly reflected. Thus in the case of a piece of glazed writing paper resting on a desk we often find a glare from the paper which is extremely trying to the eye. This is due to the fact that the light striking on such a surface is largely reflected directly into the eyes with the result that one cannot read what is on the paper and it is necessary to so move the paper that the light is no longer regularly reflected to the eye and the light received by the eye is from diffuse reflection only. If on the other hand a white piece of blotting paper were placed on the desk instead of the glazed writing paper it would be found that the regular reflection had almost entirely vanished. The white blotting paper is a good example of almost perfect diffuse or irregular reflection.

The amount of light reflected from different surfaces whether such surfaces give either regular or irregular reflection or a combination of both plays an extremely important part in the subject of practical illumination. Thus in the case of an ordinary living room with light colored paper the total amount of light as actually measured may be twice that we would get without considering the reflection of the walls, ceiling and objects in the room.

The following table taken from tests by different observers will give some idea as to percentage of light reflected from different standard wall papers, etc.:

	Per Cent. Reflection.
White blotting paper	82
White cartridge paper	80
Ordinary fools-cap	70
Ordinary newspaper	50 to 70
Chrome yellow paper	62
Orange paper	50
Plain boards (clean)	45
Plain boards (dirty)	20
Yellow wall paper	40
Tracing cloth	35
Tracing paper	22
Light pink paper	36
Blue paper	25
Yellow painted wall (clean)	40
Yellow painted wall (dirty)	20
Emerald green	18
Dark brown paper	13
Vermilion paper	12
Blue green paper	12
Cobalt blue paper	12
Black paper	0.5
Deep chocolate paper	0.4
French ultramarine blue paper	3.5
Black cloth	1.2
Black velvet	0.4

Refraction and Total Reflection.

Whenever a ray of light passes from one medium to another, such as from air to glass, it is bent out of its course, except when the ray is at right angles to the surface. Thus in Fig. 5 the ray, *A B*, passes from air into a plate of glass at the point *O*, where it is slightly bent. Where it passes out of the glass

at P, it is again bent an equal amount in the opposite direction so that the leaving ray, $P\ B$, is parallel with the entering ray, $A\ O$.

However, when the light strikes at less than a given angle (the critical angle) it will not enter the glass but will be reflected

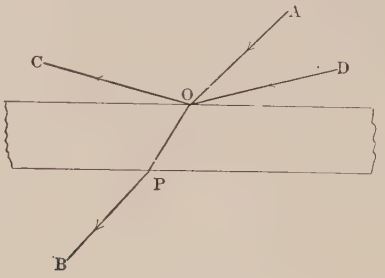


Fig. 5.— Refraction and total reflection.

as shown by the ray, $D\ O\ C$, in Fig. 5. This is called total reflection. Total reflection also occurs in the case shown in Fig. 6, where a ray of light enters a piece of prismatic glass at A is reflected at B and reflected a second time at C back in a direction parallel to that in which it came. This is what takes place in prismatic glass reflectors. In such reflectors, however,

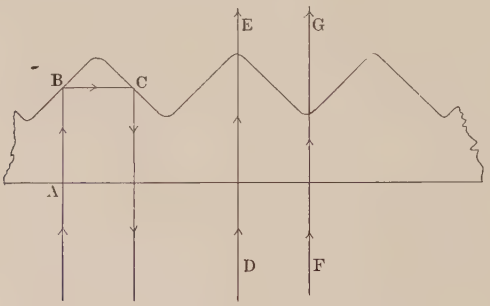


Fig. 6.— Reflection in prismatic reflectors.

some light passes straight through at the tops and bottoms of the prisms as shown by the rays $D\ E$ and $F\ G$, in Fig. 6. This is because the tops and bottoms of the prisms are slightly rounded, so that the rays do not strike them at less than the critical angle.

CHAPTER III.

LIGHT AND THE EYE.

The effect of light on the eye can perhaps best be understood by a study of the structure of the eye. Fig. 7 shows a sketch of the eye where *i* is the iris or diaphragm, or what is usually known as the colored part, as for example when we say a person has gray or blue eyes. The iris contracts and expands to regulate to a certain amount, the light which passes through the opening called the pupil, *p*, which appears as the black spot in the eye. Back of the iris is a lens, *l*, which is controlled by muscles which automatically alter its shape so as to focus the picture of the object seen on the retina, *r*, at the back of the eye-ball. The retina is a very sensitive layer on which the light

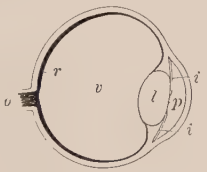


FIG. 7.— The Eye.

falls, producing a picture or image of the object seen. On the back of the retina are a large number of small nerves which combining, form the optic nerve leading to the base of the brain. The center of the eye-ball consists of a watery fluid, *v*, known as the vitreous humor. The retina is the sensitive part of the eye and while it is wonderful in its ability to recuperate it is not advisable to strain it. In order, therefore, not to injure or fatigue the eye the following points should be noted.

1. A flickering light should be carefully guarded against as the iris is unable to keep pace with the rapid fluctuations and consequently too much and too little light alternately falling on the retina very quickly produces fatigue. Examples of this

are a flickering open gas jet; an incandescent lamp supplied with current from a dynamo driven by the ordinary single cylinder gas engine; an arc lamp operated with 25-cycle alternating current, etc.

2. Lights should not be placed so that the rays from them falling on a glazed or polished surface, such as writing paper, are regularly reflected into the eye as in this case a picture of the light itself is found on the retina which obliterates the images of the writing or printing on the paper. This is commonly called glare from the paper and is not only extremely trying on the eyes but also renders almost futile the effort to see clearly.

3. Any part of the body which is subject to more violent strain than other parts is immediately noticed by contrast. Thus in the case of a severe blow on the arm, all attention is focused on it rather than on other muscles which may at the same time be only moderately injured. In the same way if a bright light is seen a picture of it is formed on the retina along with the picture of the surrounding objects. So strong, however, will be the effect of the bright light on the eye that in comparison other surrounding objects cannot be noticed. This accounts for our inability to see past a bright light. For example when walking down a street lighted with arc lights hung low we are unable to see beyond the arcs although there may be considerable light falling on objects beyond. This also accounts for the fact that if one wants to display goods in a window the wrong way to do it is to put strong glaring lights in view. Although there may be sufficient illumination on the goods displayed the effect on the retina in comparison with the glare from the source of light is small. The ability to see well means that no part of the retina should be overstimulated by means of a bright light. This necessitates keeping lights out of the field of vision and when this is not possible, keeping down their brightness by diffusing globes. The ability to see objects past or in the vicinity of a bright light is also reduced because of the fact that the iris contracts to cut down the amount of light entering the eye so as to protect the retina. This virtually makes the objects appear so dimly lighted that it is only with difficulty that we see them.

4. Light coming in large quantities from an unusual angle

should be avoided. Certain parts of the retina are, through long use, trained and accustomed to receive light while other parts are not prepared to receive strong light. In daylight we receive a gentle light from a great many directions mainly from above. If, therefore, a strong light falls on the retina in certain places it is strained. We have an example of this in snow blindness where a strong reflected light comes from below and not only produces fatigue but may also result in temporary blindness. This is also noticed where rays from a bare lamp of high candle power are allowed to fall in the eye even though the angle be considerably out of the ordinary range of vision and one is not looking at the light. For example a powerful chandelier light in the center of a church may cause discomfort to one facing it even if one does not look at the lights. Many people suffer from this even though they may not be aware of the cause of discomfort.

5. Too little light should be avoided as the retina is strained in its effort to see clearly. This is a matter of common knowledge and experience.

6. Too much light is to be avoided as the iris can contract only a certain amount and if in spite of its contraction too much light enters the pupil and falls on the retina the latter is strained just as our muscles are strained when too much effort is made. Abuse of the eyes by too much light is not as frequently found as the other abuses mentioned. However, the eye frequently receives too much light due to the causes mentioned in 2, 3 and 4.

7. Avoid sources of light which cast streaks on the work. These are bad because the source of light frequently vibrates slightly, producing the same general effect on the eye as a flickering light. Streaks are also bad, even when steady, because of the uneven illumination produced which makes it difficult for the eye to adjust itself to the conditions caused by the varying degrees of brightness. An example of this is the light cast by an ordinary green plated opal desk shade or a polished metal reflector such as tin or aluminum with a clear bulb incandescent lamp inside. This subject is taken up further in the chapters on reflectors.

8. Care should be taken to avoid a sharp contrast between a light surface on which one is working and dark surroundings

such as, for example, a brilliantly lighted desk with the rest of the room in darkness. Too sharp a contrast is injurious for the reason that the eye does not have an opportunity to adjust itself to the different conditions when glancing up from the work. On the other hand, a moderate change in the illumination is good. The eye is rested thereby as when attention is focused strongly and constantly on one thing the eye requires a change both in the illumination and in the image on the retina in order to give it an opportunity to recuperate.

Oculists are constantly coming across cases of temporary or permanent injury to the eyes through neglect of one or more of the precautions enumerated. It is likely that many others who are not forced to resort to the oculist realize considerable discomfort and annoyance. Those who have been working almost entirely by artificial light surrounded on all sides by glaring undiffused lights have sometimes reached the point where the light is unendurable and have had to give their eyes complete rest after which it is impossible for them to work continuously by artificial light and it is only possible for them to use artificial light with comfort by avoiding all the mistakes which have just been enumerated.

CHAPTER IV.

CALCULATION OF ILLUMINATION.

Before being able to calculate the illumination obtained from any source of light it is necessary to know the candle power of the rays thrown in various directions by this source. Fig. 8 shows the strength of the light thrown in different directions in a vertical plane about a bare 16 candle-power incandescent electric lamp. The candle powers at the various angles as marked on this diagram were obtained by means of a photometer. The dotted curve surrounding the lamp is called a photometric curve,

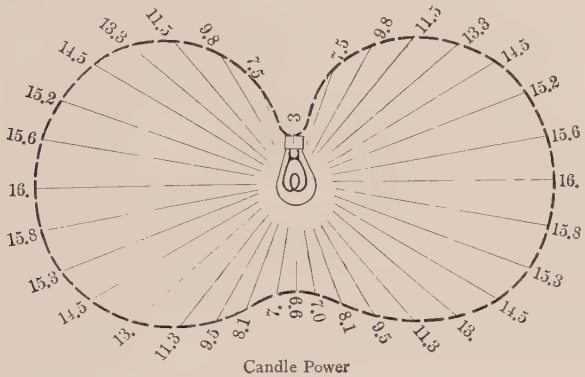


FIG. 8.— Photometric curve of bare incandescent lamp.

because its distance from the center where the lamp is located is proportional to the candle power at any given angle as determined by a photometer. In other words, the length of the radial line represents the candle power. We see that the candle power varies considerably at different angles. At the horizontal it is 16. Directly underneath it is only 6.6. The distribution of light is varied greatly by the use of reflectors as can be seen by the large number of tests given later in the chapters on reflectors, shades and globes.

Some illuminants do not give the same amount of light when viewed from different directions in a horizontal plane. In such cases, it is therefore customary to make horizontal distribution curves showing these variations. With most sources of light, such curves are usually circular as they give practically the same amount of light in different horizontal directions. Thus with the incandescent electric lamp, the open flame gas lamp, individual mantle burners either upright or inverted, and acetylene lamps, this holds true, but it does not with electric arc lamps, gas arc lamps, Nernst lamps and most vapor lamps so that in such cases it is customary to take the mean of readings made in different vertical planes and assume this as giving the vertical distribution curve of the source of light. This lack of uniformity in horizontal distribution is sometimes of great practical importance and will be considered in detail when considering such sources of light.

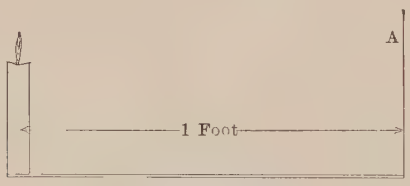


FIG 9. – Foot candle.

In the United States intensity of illumination on any surface upon which light falls is usually expressed in foot-candles.

If a standard candle is set one foot from a perpendicular wall as in Fig. 9, the illumination on the wall at the point A will be one foot-candle. If the candle were two feet from the wall the intensity at the point A would be 0.25 foot-candle which is obtained by dividing 1, the candle power of the source of light, by 4, the square of the distance in feet, as was shown in Fig. 1. We then have the rule:

To find the foot-candle intensity of light on a surface at right angles to the ray of light, divide the candle power intensity of the ray by the square of the distance in feet.

Expressed mathematically, this would give the formula:

$$I = \frac{cp}{d^2}$$

where

I = intensity of illumination in foot-candles
cp = candle power in the given direction
d = distance in feet.

This rule does not hold true for surfaces not at right angles to the ray of light. This will be taken up later. Surfaces at right angles to a ray of light are usually spoken of as normal to the ray and in figuring the illumination of such surfaces the term normal illumination is used.

To take a further example of normal illumination, suppose that it is wished to determine the illumination on a reading page held at right angles or normal to the ray of light thrown by a 16 candle power lamp in the fluted opal cone reflector which is shown in Figs. 19 and 20. We will suppose further that

FIG. 10.— Normal illumination.

the page is held 30 degrees from a vertical line drawn through the lamp, and is three feet from the lamp as in Fig. 10. From Fig. 19 it is seen that the candle power intensity of that ray 30 degrees from the vertical is 24.5. The intensity in foot-candles of the light falling on the reading page will be 24.5 candle power divided by the square of three feet which gives as a result 2.7 foot-candles.

If the foot-candle intensity of light on a surface not at right angles to the ray of light is wanted, the foot-candles can be calculated for a surface at right angles to the ray as before and this result multiplied by the cosine of the angle between the ray of light and a perpendicular drawn from the lamp to the illuminated surface. Thus in Fig. 11 with the lamp at S and the illumination to be determined at point B, the normal illumina-

tion in foot-candles on point B must be multiplied by the cosine of the angle a, this being the angle between the ray $S\ B$, and the perpendicular $S\ D$.

Expressed mathematically, this would give the formula:

$$\text{Horizontal } I = \frac{cp}{d^2} \cos a.$$

where the letters have the same meaning as in the last formula. The cosine of any angle can be found in a table of cosines such as is used in trigonometry but those who are not familiar with trigonometry and the use of such tables as well as those who are familiar with them can get the desired results more quickly by using the following rule the method of obtaining which is based on a formula which it is not necessary to discuss here. This rule is: To determine the illumination on a horizontal sur-

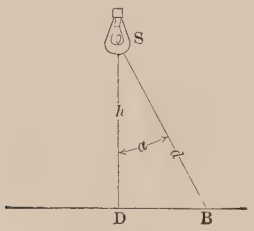


FIG. 11.— Horizontal illumination.

face (such as a table or floor) multiply the candle power intensity of the ray by the cube of the cosine of the angle between the ray and the perpendicular (this cube of the cosine of any needed angle being found in the accompanying table) and divide this result by the square of the height, in feet, of the lamp above the surface. The result is the horizontal illumination in foot-candles.

Expressed mathematically this would give the formula:

$$\text{Horizontal } I = \frac{cp}{h^2} \cos^3 a.$$

where

Horizontal I = Foot-candle illumination on surface,

h = perpendicular distance, in feet, from lamp to surface.

a = angle between ray and perpendicular,
cp = candle power in the given direction.

EXAMPLE:—Calculate the horizontal illumination on a dining room table four feet square, illuminated by a 16-c.p. lamp equipped with the opal dome reflector shown in Figs. 21 and 22, hung on a pendant three feet above the center of the table.

TABLE OF COSINES CUBED.

Angle.	Cos^3	Angle.	Cos^3	Angle.	Cos^3
1°	1.000	29°	.668	57°	.161
2	.998	30	.649	58	.149
3	.998	31	.630	59	.137
4	.993	32	.610	60	.125
5	.988	33	.590	61	.114
6	.983	34	.570	62	.103
7	.978	35	.550	63	.0936
8	.971	36	.529	64	.0842
9	.963	37	.509	65	.0754
10	.955	38	.489	66	.0671
11	.945	39	.469	67	.0596
12	.935	40	.449	68	.0526
13	.925	41	.429	69	.0460
14	.913	42	.410	70	.0400
15	.901	43	.391	71	.0345
16	.888	44	.372	72	.0295
17	.874	45	.353	73	.0250
18	.860	46	.335	74	.0209
19	.845	47	.317	75	.0173
20	.829	48	.300	76	.0142
21	.813	49	.282	77	.0114
22	.797	50	.265	78	.00900
23	.780	51	.249	79	.00695
24	.762	52	.233	80	.00523
25	.744	53	.218	81	.00383
26	.726	54	.203	82	.00270
27	.707	55	.189	83	.00181
28	.688	56	.175	84	.00114

The best plan is to begin by making a drawing to scale, as in Fig. 12. With the lamp as a center, draw lines $A\,B$, $A\,C$ and $A\,D$ every 10 degrees. The illumination directly under the lamp will be the candle power 29.3 divided by 9, the square of the height, multiplied by 1, the cube of the cosine of 0 degrees, which gives 3.2 candle feet illumination at point B. To find the illumination at point C take the candle power of the ray 10

degrees from the vertical which is seen from Fig. 21 to be 29. Then multiply this candle power, 29, by .955 which is the cube of the cosine of 10 degrees found in the table. This product divided by 9, the square of the height, gives 3.0 which is the illumination in candle feet at point *C*. The illumination at point *D* is 25.5 candle power multiplied by 0.829 and divided by 9, giving 2.3 candle feet. This process is repeated for each angle at which the illumination is desired.

In order to bring out the foregoing facts more clearly, take the case of a hall (the plan is shown in Fig. 13), which is 80 feet long, 50 feet wide and twenty feet high, with the lamps located as shown in the drawing. This is lighted by six gas arc lamps with alabaster globes, hung 15 feet from the floor. In the upper

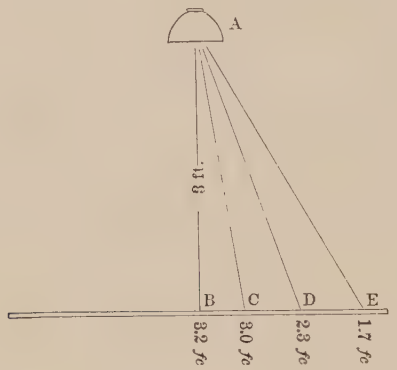


FIG. 12.— Calculation of horizontal illumination.

left hand corner of Fig. 14 is a photometric curve of such a gas arc lamp only one quarter of the curve being shown. The complete curve is shown in Fig. 196 in Chapter XI. This can be drawn to any convenient scale. Assume that the plane to be illuminated is three feet above the floor which would place the lamps 12 feet above the plane to be illuminated. Then draw a horizontal line to scale 12 feet below the position of the lamp in the photometric curve to represent the plane to be illuminated and on this measure off different distances from the foot of the perpendicular all, of course, on the same scale, as shown in Fig. 14. Then draw lines from these different distances toward the source of light until the photometric curve is intersected, as shown in Fig. 14. Near the perpendicular the distances

should be laid off rather close together, but further away they can be more widely spaced, inasmuch as the change in the value of illumination takes place slowly as we get further from the lamp, and intermediate values can easily be estimated. We can then prepare the table as shown in the upper right hand corner in Fig. 14. The angles a can be determined in one operation by placing a protractor over the diagram. The values of the different candle powers can be obtained by measuring to the same scale as that on which the curve was laid out The value of the horizontal illumination at each point after the candle power and the angle is known, can be at once determined by multiplying the candle power by the cube of the cosine of the angle and dividing by 144, the square of the height.

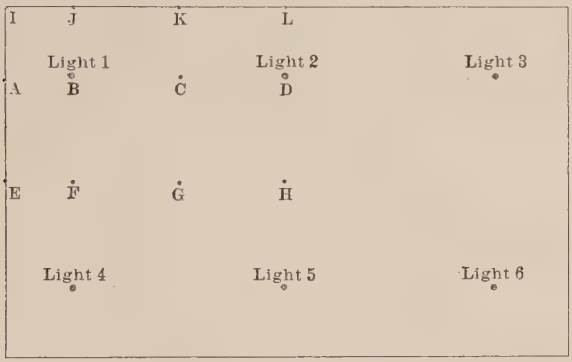


FIG. 13.— Plan of hall 50 x 80 ft.

This can be done most rapidly by the use of a slide rule. As a check to the work, also as an aid to the eye to show how the illumination varies at different distances from the light, it will be desirable to draw the illumination curve shown on the lower part of Fig. 14. The height of this curve from the base line at any point represents the foot-candles. The values of the horizontal illumination can be plotted to any convenient scale.

After obtaining these values we can then determine the illumination at different points in the room. In Fig. 13 twelve points have been selected as indicated by the letters A, B, etc. These twelve points give practically all the variation in illumination possible. It will be convenient in determining the illumination at the different points to prepare a table as shown

herewith which shows the distance of the points from the lamps and the illumination therefrom. The different distances of the sources of light from any given point can be at once obtained by measuring them with a scale rule, on the plan, Fig. 13. When the value of the illumination at any point is less than five per cent. of the maximum illumination falling on the same from any one lamp, such values can be neglected. In the table where a dash occurs it means that the illumination from the

VALUES OF HORIZONTAL ILLUMINATION AT THE 12 POINTS INDICATED IN FIG. 13.

	Ft.	A	Ft.	B	Ft.	C	Ft.	D	Ft.	E	Ft.	F
Light 1	10	.570	0	1.11	15	.362	30	.093	18	.274	15	.362
" 2	40	.046	30	.093	15	.362	0	1.110	42	.040	34	.067
" 3	—	—	—	—	45	.030	30	.093	—	—	—	—
" 4	31	.084	30	.093	33	.072	42	.040	18	.274	15	.362
" 5	—	—	42	.040	33	.072	30	.093	42	.040	34	.067
" 6	—	—	—	—	—	—	42	.040	—	—	—	—
Total		.70		1.34		.90		1.47		.63		.86

	Ft.	G	Ft.	H	Ft.	I	Ft.	J	Ft.	K	Ft.	L
Light 1	21	.208	34	.067	14	.396	10	.570	18	.274	32	.076
" 2	21	.208	15	.362	41	.043	32	.076	18	.274	10	.570
" 3	—	—	34	.067	—	—	—	—	46	.028	32	.076
" 4	21	.208	34	.067	41	.043	40	.046	43	.037	—	—
" 5	21	.208	15	.362	—	—	—	—	43	.037	40	.046
" 6	—	—	34	.067	—	—	—	—	—	—	—	—
Total		.83		.99		.48		.69		.64		.77

lamp is so small that in comparison with the effect of the other lamps, it can be neglected. Having obtained the value of the illumination at different points as shown in the table, it will sometimes be found convenient to plot the resultant illumination obtained by adding the illumination from the different lamps falling on each point to show graphically the variations.

Fig. 15 shows the value of the illumination at the different points in three planes lengthwise of the hall. Similar curves could be plotted to show the variation of the illumination cross-

wise of the hall. It will be noted that the illumination along the sides of the hall is considerably lower than that through a row of lamps or in the center. This value, however, along the sides will be considerably raised by the reflection from the walls and ceiling provided these are light in color. It is probably

D	a	$\cos^3 a$	c.p.	Horizontal I
0	0.	1.000	160	1.11
1	4.5	.990	165	1.13
2	9.	.963	174	1.16
3	14.	.913	185	1.17
4	18.	.860	195	1.16
5	22.	.797	196	1.10
6	26.	.726	188	.950
7	30.	.649	183	.830
8	33.5	.580	182	.734
9	36.5	.519	182	.657
10	39.5	.459	183	.570
12	45.	.353	189	.463
14	49.	.282	202	.396
16	53.	.218	216	.327
18	56.	.175	225	.274
20	59.	.137	235	.224
24	63.	.0936	244	.159
28	66.5	.0633	250	.110
32	69.5	.0430	256	.0765
36	71.5	.0320	260	.0596
40	73.	.0250	267	.0464

$$\text{Horizontal I.} = \frac{\text{c.p.}}{h^2} \cos^3 a$$

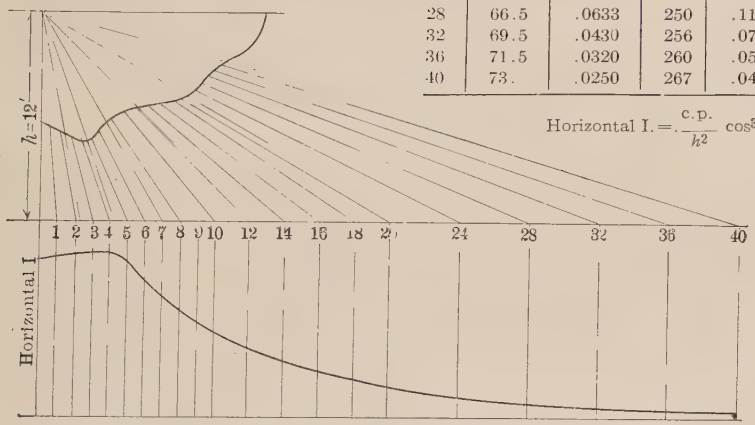


FIG. 14.— Photometric and illumination curves of "Gas Arc."

safe to assume that the values of the illumination in this room will be raised at least 50 per cent., providing the colors are light. In this connection it is well to note that the amount to be allowed for the reflection of the walls and ceiling depends upon the amount of light which is thrown on them. If, for example, reflectors were used on the lamps so that practically

no light was allowed to fall on the ceiling and but little on the walls, but very little could be allowed for reflection even though the color effects were light. If on the other hand, as in this case, half of the light is above the horizontal as will be noted by referring to Fig. 196, a large margin can be allowed for reflection. It has been shown by Mr. Preston S. Millar in a paper before the Illuminating Engineering Society in Nov. 1906, that the reflection from walls and ceilings may increase the illumination as much as 166 per cent. with light buff walls and ceilings and lamps at the ceiling without reflectors.

Primarily in calculating the illumination one should consider whether or not horizontal or normal illumination should be used. When a book or paper is held in such a position that the maximum amount of light from any given source falls upon it, one should figure on normal illumination. It is evident, however, that if the book were held in this position one could not figure on its receiving normal illumination from some other source

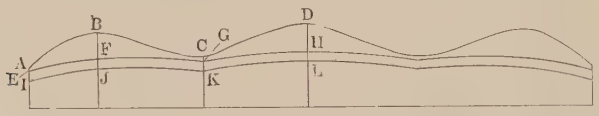


FIG. 15.—Illumination on three planes of hall.

of light that might be in the room. If it is desired to obtain a definite illumination from the two sources of light the book would have to lie horizontally. If then, as is ordinarily the case, it is desired to determine the illumination at any point in the room from a number of sources of light, one should use the horizontal illumination rather than the normal.

If it is desired to calculate the illumination on the walls, or what is known as vertical illumination in one vertical plane, it is simply necessary to turn the photometric curve through 90° and consider instead of the height above the floor the horizontal distance from the source of light to the wall.

The authors have omitted here consideration of the case of lamps hanging at an angle inasmuch as this problem is rather involved and too complicated for ordinary calculation.

QUANTITY OF LIGHT.

In laying out lighting for any purpose it is first best to determine, at least approximately, the quantity of light to be used.

The approximation can later be revised after calculations are made, in case too much or too little light has been assumed.

The amount of light necessary for good illumination depends upon the purpose for which the place to be lighted is to be used and also on the individual's ideas on the subject. Thus the requirements for street, house and office lighting present great differences. Further the amount of light necessary depends largely upon the character of the surrounding surfaces, such as walls, ceiling, etc., as well as upon the absorption of the shades, if such are used, as well as their directing power.

It is safe to say that the increase in illumination by reflection from walls and ceilings may be anywhere from 5 to 200 per cent. depending on the color of the walls, the size of room and the location and equipment of lamps. At present writing actual tests on this subject are few.

There are four methods in general use by which the quantity of light necessary can be approximated.

1st. The number of candle power per square foot.

2d. The number of candle power per cubic foot.

3d. The watts per square foot (used of course only in the case of electric light).

4th. The number of foot-candles.

The best practice where actual work is concerned is to use all four methods if the rooms are large.

The mean spherical candle power of the lamps to be used should preferably be made the basis of calculations rather than the rated candle power, as the latter figure in some cases means very little. To correctly judge the efficiency of a source of light not only the rated (which is generally the maximum) light but also the light given in other directions, must be taken into account; that is, the mean spherical candle power. In other words, if the source of light in question should give the same total amount of light, but equally in all directions we would term this the mean spherical candle power. In an oval anchored filament incandescent lamp the mean spherical candle power is about 85 per cent. of the rated horizontal candle power. With the upright mantle gas burner it is about 76 per cent. With the open gas jet the percentage is nearly 100.

The amount of light per square foot, as before noted, varies widely, being in some cases as high as one candle power per

square foot, where a very strong light is desired, and again as low as one candle power per five square feet in a large room where simply a general illumination is required. The mean of these two or about one candle power per three square feet, when the allowance for reflection from walls and ceilings is about 50 per cent., is a good working basis for ordinary illumination.

Thus in the case of the room Figs. 13, 14 and 15, we have $2\frac{3}{4}$ square feet per mean spherical candle power; the mean spherical candle power of the gas arc lamp used being given in connection with Fig. 196. This also checks up with the other methods inasmuch as an allowance of 55 cubic feet per candle power has been made and as, allowing 50 per cent. for reflection from walls and ceiling the average foot candles on the plane illuminated is about 1.3.

For the cubic foot basis the height of the lamps from the floor plays an extremely important part. In practice, however, it is safe to allow one candle power for from 25 to 50 cubic feet. The latter is sufficient in places where the walls are of light color, but where dark, would not be satisfactory.

Under the fourth method 0.5 of a horizontal foot-candle will give a fair illumination. For reading purposes this should be raised to a minimum of one foot-candle, and for lighting desks this should be increased to from two to five foot-candles for best results. Drafting tables require from five toten foot-candles.

CHAPTER V.

INDIVIDUAL INCANDESCENT ELECTRIC LAMPS AND THEIR REFLECTORS, SHADES AND GLOBES.

In designing illumination it is usually important to consider not only the location of the lamps but the candle power given in various directions by each light. In other words, each source of light, together with the reflector, globe or shade which accompanies it, must be considered as a unit before arriving at any conclusion as to the illumination. In the majority of cases where the resultant efficiency is any object, it is desirable to have some means of directing the rays from the sources of light, so that the strongest light will fall where most wanted. Manifestly, it is of first importance to know what various types of reflectors, shades and globes will accomplish in this respect, as there is an immense difference in the distribution of light with different forms of glassware.

Reflectors, shades and globes are used for three purposes: (1) Softening and diffusing the light, (2) directing the rays of light in certain useful directions, (3) for ornament. A reflector shade or globe may combine in one all these three characteristics, or it may have only one of them. It is too often the case that the one chosen is not the right thing for the place, or is chosen for its general appearance without any attempt to learn what it practically accomplishes in the way of altering the natural distribution of light from the lamp.

The reader can best be brought to realize the importance of a proper choice of reflectors and the great difference between reflectors, shades and globes by a study of tests made on lamps variously equipped, showing the amount of light thrown in different directions above and below the lamp. All of the following diagrams or photometric curves were taken from tests made by the Electrical Testing Laboratories of New York, except where otherwise specified.

Fig. 16 shows the candle power or intensity of the light thrown in different directions, in a vertical plane from a bare 16-candle power, oval anchored filament incandescent lamp with a clear glass bulb suspended vertically, as indicated in the diagram, and without any reflector or globe. It is seen that the lamp gives 16-candle power in a horizontal direction. In other directions the light is less. Directly below the lamp, the candle power is 6.6. It is evident that a bare lamp like this, hung in a room, will throw more light in the directions of the walls than anywhere else. Nearly one-half will also go toward the high side walls and the ceiling. There are certain places where this is desirable, as in warehouses and storage rooms.

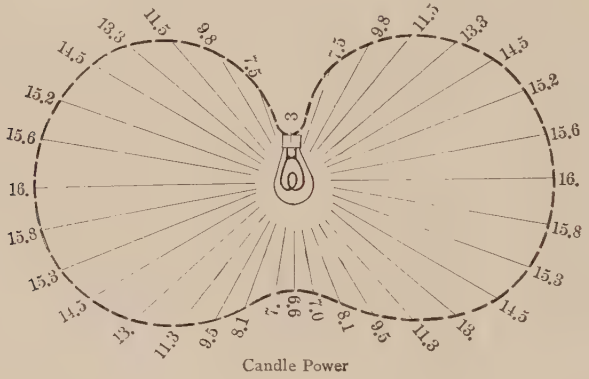


FIG. 16.—Light about a bare incandescent lamp.

Fig. 17 gives the light distribution about an incandescent lamp with a bulb frosted by being etched with acid. This test was made after frosting the same lamp on which the test (Fig. 16) was made. By the term frosting is here meant the usual process of producing a rough surface on the glass itself by the use of acid, and not the coating or painting of the surface of the glass with white frosting. The latter process, known as dipping, is not as satisfactory, because unless a thick enough coat is applied to seriously cut down the light the glare from the bare filament is but imperfectly diffused. This test showed the absorption or loss of light due to frosting amounted to 11.5 per cent. The mean of other tests given at the end of this chapter show only ten per cent. loss. In Fig. 16 the mean

spherical candle power from the clear glass bulb incandescent lamp was 13.2. After frosting the bulb as in Fig. 17 the mean spherical candle power was 11.7. The frosting of the bulb, it is seen, does not change the distribution of light about the lamp materially, but simply reduces the amount of light thrown in all directions, except directly below the tip of the lamp, where the candle power is increased from about 6.6 to 8.9. The loss of 11.5 per cent of the light by frosting of the bulb is more than made up for in all locations where the lamps are placed within the line of ordinary vision; that is, when their rays fall directly in the eyes. The frosting of the glass diffuses the light so that it does not have the blinding effect that the bare incandescent filament has upon the eyes. Thus, although

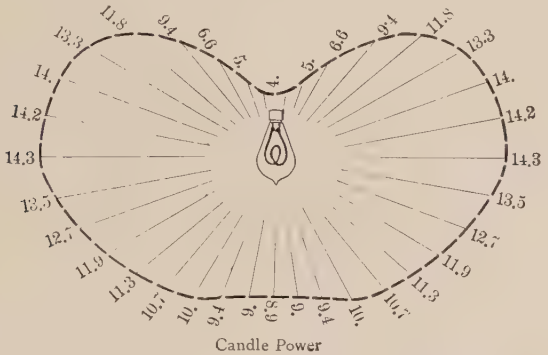


FIG. 17.—Light about a frosted incandescent lamp.

the actual amount of light may be reduced 11.5 per cent, or more, one can really see better, and therefore the illumination is better, with the frosted bulb lamps wherever the lamps are so located that the rays fall directly in the eye. For this reason it is desirable to use a frosted bulb in most locations where an incandescent lamp is to be used without reflectors or globes, which completely hide the filament. It is much easier to see beyond a frosted bulb lamp which is nearly in the line of vision than to see beyond a lamp with a clear glass bulb, for reasons explained in the chapter on Light and the Eye. In some places where it is desirable to use frosted bulbs, there is so much dirt that their use is inadvisable, because a rough frosted glass when it is once dirty is difficult to clean.

A point open to argument is whether, if a diffusing cover is wanted, it is better to use a frosted bulb lamp rather than a surrounding globe of frosted, ground or sand-blasted glass. This is taken up later in the close of this chapter.

One thing decidedly in favor of frosted as against clear glass bulbs is their artistic appearance. The light from them is much more pleasing than from the clear bulb, which exposes the filament.

Frosted or sand-blasted bulbs so diffuse the light as to overcome the streaks which are quite pronounced with the clear glass bulb. These streaks are very objectionable where reading writing, draughting or any kind of close work is to be done. They cause a strain on the eyes which the user of the light is generally not aware of, and for that reason are especially to be avoided.

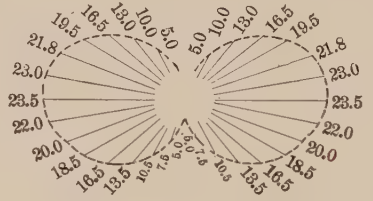


Fig. 18.—Light about a tantalum filament lamp.

Where there is a mixture of daylight and artificial light, that from an incandescent lamp with a clear glass bulb lamp is likely to present a sickly yellow appearance. This sickly appearance can be very much reduced, although not entirely eliminated by the use of frosted or sand-blasted glass. This should be remembered in the lighting of stores, halls of hotels and office buildings, and all places where considerable light from incandescent lamps must be used during daylight hours in combination with daylight. Even at night the frosted glass greatly improves the appearance of incandescent electric lamps.

Fig. 18 shows the distribution of light about a tantalum metallic filament lamp, this test being one made by Dr. Louis Bell and Prof. W. L. Puffer, at the Massachusetts Institute of Technology, and given in the *Electrical World and Engineer*, June 3, 1905. The filament of this lamp is supported on a

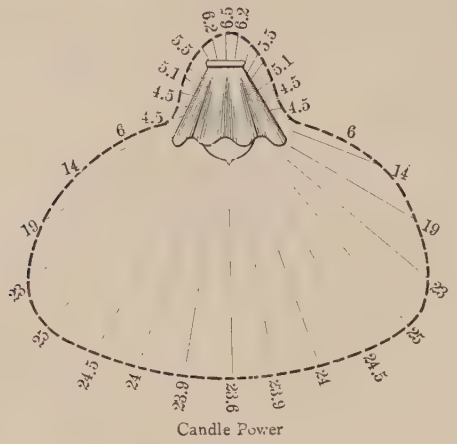
spider in such a way that the horizontal candle power is greater in proportion to the mean spherical than in the ordinary 16-candle power, carbon, oval anchored filament lamp. The mean spherical candle power of this tantalum lamp is 17.4. The watts consumed per mean spherical candle power are about 2.53, the watts per horizontal candle power being about 1.85. These lamps, as made in America, require about two watts per horizontal candle power. This lamp calls for the same treatment as regards reflectors, shades and globes as the regular carbon filament incandescent lamps.

Opal Glass Reflectors.

Fig. 19 gives the light distribution about a 16-candle-power incandescent lamp covered with what is commonly known to the trade as a fluted opal cone reflector 6.5 inches in diameter, the form of which is shown in Fig. 20. This is one of the best and most efficient of the common cheap types of reflectors. It is useful wherever a large amount of light from the lamp is needed below the horizontal. It so changes the distribution of light about the incandescent lamp as to throw from 23 to 25 candle power in all downward directions below 45° from the horizontal. The performance of opal reflectors of this kind depends somewhat upon the density of the opal glass used. The more dense the opal the greater the amount of light reflected and the less that passing through the reflector. This particular reflector is fairly dense and hence lets comparatively little light escape above the horizontal. Enough, however, goes through the reflector to keep the walls and ceiling of a room from being in darkness. Such a reflector can properly be used in all cases where it is not objectionable from an artistic standpoint, and it is desirable to direct the light downward and at the same time allow a small amount of light to go to the walls and ceilings.

This opal cone reflector does not give anywhere near as great a maximum downward candle power as some of the reflectors which will be shown later, but it illustrates very well what a great difference can be made in the amount of light thrown down from a lamp placed in a pendant position by the use of the proper reflector. Thus, for example, this reflector gives a candle power directly below the lamp (that is, a tip candle power) of 23.6 and at the angle of 40 degrees from the vertical,

a candle power of 25. The bare lamp would give only 6.6 candle power at the tip and less than 12 candle power at the angle of 40 degrees from the vertical. As lamps are so frequently placed high up in a room on chandeliers or pendants or sometimes at the ceiling, the importance of directing the rays down



Candle Power

FIG. 19.—Light about a fluted opal cone reflector.

so that they will be of use to the occupants of the room is apparent.

The ceilings and walls if light in color have considerable value as reflectors and diffusers. Where maximum efficiency is desired, it must be remembered, however, that a reflector to

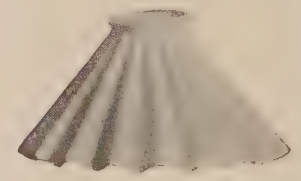


FIG. 20.—Fluted opal cone reflector.

be efficient must fit over a lamp and not be some distance from it, and that further, without reflectors much of the light is reflected back and forth from wall to wall two or three times with much loss each time before it reaches the place that specially needs illumination.

Fig. 21 shows the distribution of light about a 16-candle power incandescent lamp in a white opal dome reflector, the form of which is shown in Fig. 22. This is an excellent reflector for many common uses. Being 3.75 inches deep and 7.25

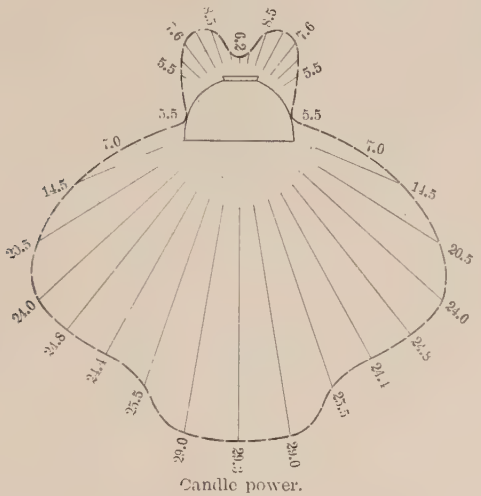


FIG. 21.—Light about a 7-in. opal dome reflector.

inches in diameter, it covers the lamp so as to act as a diffusing globe, to a certain extent, while at the same time it gives an excellent distribution of light in all downward directions, the maximum being somewhat over 29 candle power. It is a good

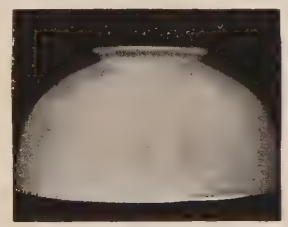


FIG. 22.—7-in. opal dome reflector.

type of reflector to place pointing straight downward over the center of a dining-room table, one lamp giving illumination over the entire top of a fairly large table. (See Fig. 12.) It can also be used on chandeliers for the general lighting of all classes of

rooms. When so used it should be pointed straight down, because if placed at an angle it will give more light than is necessary on the high side walls. It is interesting to compare this with the opal reflectors, Fig. 19 and 23. The maximum candle power of this opal dome reflector is considerably greater than from the fluted opal cone, shown in Fig. 19. This candle power extends about ten degrees each side of the vertical, and

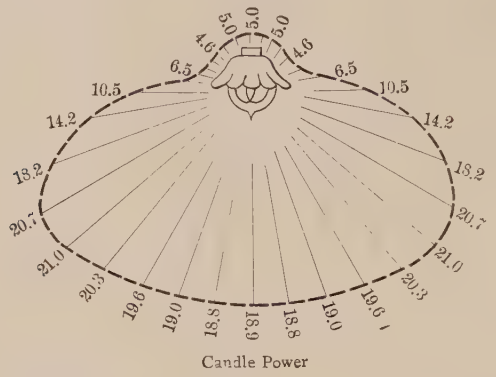


FIG. 23.—Light about an opal bell reflector.

the balance of the distribution is very similar to that of the fluted opal cone. This would be a good reflector for reading and desk use, but for the fact that having a smooth reflecting surface, the light is somewhat streaked. The streaks can be overcome by the use of a frosted bulb lamp, as in other types of smooth reflectors. Although not specially ornamental in its usual form, as found on the market, it could easily be made

FIG. 24.—Opal bell reflector.

so. It is another good example illustrating how little attention is commonly paid to combining the useful and artistic in glassware and how much room there is for improvement and development along this line.

In Fig. 23 is shown the light distribution about a 16-candle power incandescent lamp equipped with a five-inch opal bell reflector of the type shown in Fig. 24. This is a very common

type of reflector and is excellent for securing general distribution of light in all downward directions where it is not desired to concentrate a great amount of light at any one point. As the lamp bulb projects a considerable distance out of this reflector,

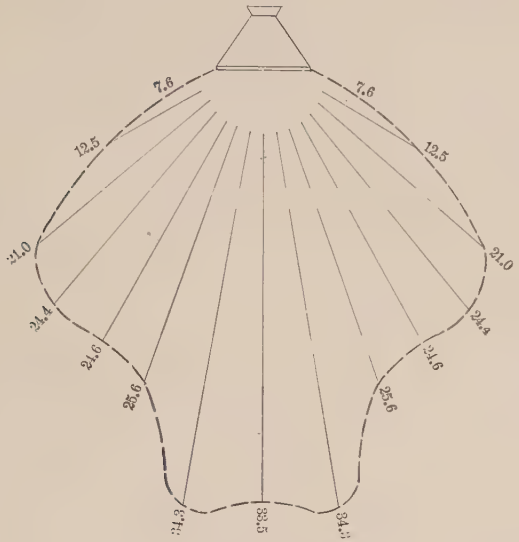


FIG. 25.—Light about a green plated opal desk shade.

it is frequently necessary to use it with a frosted bulb lamp on account of the large amount of exposed filament. If such a reflector is to be used on a chandelier of ordinary height in a small

FIG. 26.—Green plated opal desk shade.

room, the chandelier should preferably be equipped with sockets pointing straight down or nearly so in order that an unnecessary amount of light be not thrown upward. Such a reflector put on a chandelier with lamp sockets at an angle of 45 degrees

will evidently throw much more light upward than is necessary unless there happen to be pictures or other objects high in the room which are to be illuminated.

Fig. 25 gives the light distribution about a 16-candle power incandescent lamp equipped with an opal desk shade seven inches in diameter with green backing, shown in Fig. 26. This

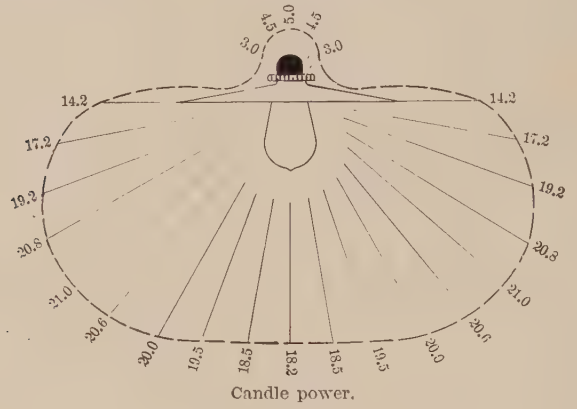


FIG. 27.—Light about a flat opal reflector.

is the type of shade most commonly found in offices to-day. It is, of course, intended to concentrate light below the tip of the lamp for office desk purposes and let but little light through where it can reach the eyes of the users. The maximum candle power is about 34. The candle power tests on this shade do not show the very objectionable feature of it, namely, that it

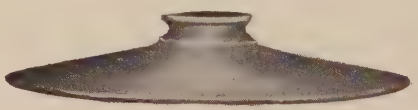


FIG. 28.—Flat opal reflector.

throws a very streaked light. A frosted bulb lamp should invariably be used with such a shade, as this would eliminate the streaks and make its use tolerable. Otherwise it should be prohibited by law.

Fig. 27 gives the light distribution about a flat opal reflector ten inches in diameter, the form of which is shown in Fig. 28.

The reflector so changes the natural distribution of light from an incandescent lamp as to give an increase of light in all directions below the horizontal and very little above the horizontal. It is good to use wherever it is desired to light dimly a large area from one lamp without concentrating much light below the lamp. Its most extensive application is in basements, where it should be placed near the ceiling to keep the lamp out of the line of vision, and also in halls of the cheaper class of buildings. It does not throw enough of its light down to fit it for use on high ceilings. One of its chief disadvantages is that it leaves the lamp absolutely unshaded so that frosted lamps should be used with it both to diffuse the glare and obviate the streaked light from the bare filament.

Prismatic Glass Reflectors.

The principle of the prismatic glass reflector was shown in Fig. 6, Chapter II. In this the reflection is accomplished by means of prisms pressed in the glass. The popularity of this class of reflectors lies in the fact that they can be designed so as to give almost any kind of a downward distribution of light desired while at the same time enough light passes through the glass without reflection so that the ceilings and upper walls of a room are not left in darkness. Some of these reflectors are designed to be very powerful concentrators of light, while others distribute the light over a wide angle below the lamp, giving an even illumination over a large area. In the practical application of light, very many cases arise where it is desired to have the greater part of the light concentrated under the lamp, and yet where it is not desired to have the reflector entirely opaque. The prisms break up the light rays so that the reflected light with these types is almost free from streaks. They have also the advantage over opal and ground glass that the dirt which inevitably collects on reflectors in some locations does not show as badly as on opal or ground glass. That collecting on top of the reflector does not interfere with its reflecting power.

Not every glass reflector that has corrugations upon it is to be considered a true prismatic reflector. The prisms must be accurately made and the reflector correctly shaped. Such reflectors should not be selected on appearances or shape, but rather from photometric tests which show just what light dis-

tribution they give. In the absence of such tests or their equivalent one is working absolutely in the dark.

Fig. 29 shows the distribution of light about a 120-watt Meridian incandescent lamp with a prismatic reflector. This lamp had the old style common carbon filament, not the new, high efficiency Gem filament. This lamp, which is shown in Fig. 30, has a large spherical frosted bulb. The upper part of the bulb coming next to the reflector is not frosted. It will be seen that

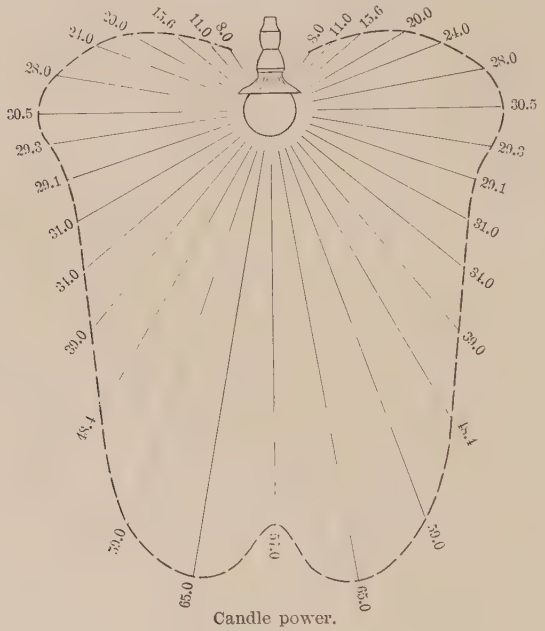


FIG. 29.—Light about 120-watt meridian lamp with prismatic reflector.

this gives a fairly concentrated downward light. It should not, therefore, be attempted to make this lamp cover too great an area. On account of its artistic appearance, the lamp is well adapted to use on a ceiling to be studded with a number of lights, or for the lighting of a small room with one central light at the ceiling. It is also suited for use on chandeliers where a concentrated light is desired below the chandelier. As a light producer this lamp is very similar to a standard frosted bulb 32 candle power incandescent lamp equipped with a similar

reflector. Its cost is somewhat higher than the standard lamp, but its appearance is by some considered enough better to justify the expense.

We will now take up several representative types of prismatic glass reflectors designed for use over standard incandescent lamps with standard shade holders. As many of the photometric tests on these reflectors are obtainable from their manufacturers upon application, it will not be necessary here to give anything further than the tests of a few representative types. Only enough tests will be given to afford the reader a good idea of what the various types accomplish and how they compare with other kinds of reflectors.

FIG. 30.—120-watt meridian lamp.

Fig. 31 shows the distribution of light about a 16-candle power incandescent lamp in the prismatic reflector, shown in Fig. 32, which is in extensive use, and concentrates a large amount of light below the lamp. The maximum candle power for an angle of a few degrees is as high as 57, while it gives more than would the bare incandescent lamp at all angles below 30 degrees from the horizontal. This reflector is suited to all locations where concentrated light is desired at one point, without distribution over a wide area. This includes desk lamps and reading lamps on downwardly pointed pockets on chandeliers. It would be a mistake to attempt the general illumination of a

large room with this particular reflector unless a number of lamps pointing in various directions were used on a chandelier, or unless they were studded over the ceiling.

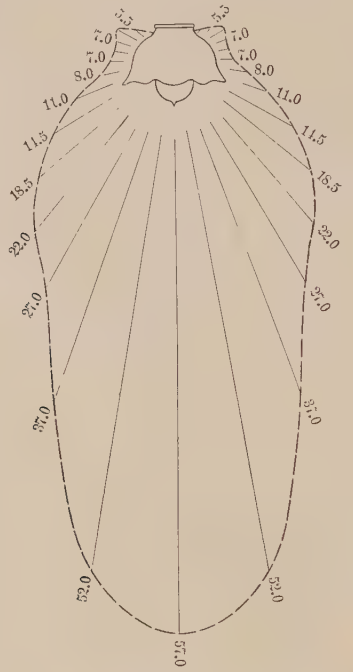


FIG. 31.—Light about a prismatic reflector.

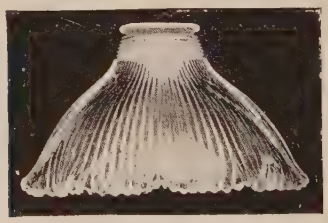


FIG. 32.—Prismatic reflector.

Fig. 33 shows the distribution of light about a 16-candle power incandescent lamp in the prismatic reflector shown in Fig. 34. It does not concentrate the light as much as the reflector shown in Fig. 31, and for that reason will be found of more general

application than the former, as there are many cases where the light from the other would be too much concentrated at one point.

Fig. 35 shows the distribution of light about a 32-candle power incandescent lamp in the prismatic reflector shown in

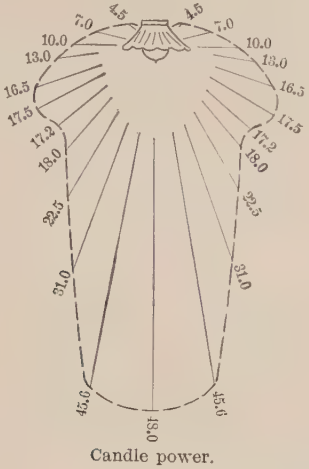


FIG. 33.—Light about a prismatic reflector.

Fig. 36. It represents an extreme case of concentrating light over a small area, yet at the same time a limited amount escapes through the reflector, so that it is not entirely opaque. The same reflector with a 16-candle power lamp gives about 120-

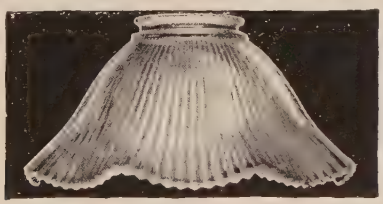


FIG. 34.—Prismatic reflector.

candle power at the tip. A reflector of this kind is manifestly suited only to places where a small but very concentrated beam of light is wanted, as in lighting store windows, draughting, lighting of small desks, and pendant reading lights used by one person only.

Fig. 37 shows the distribution of light about a 16-candle power incandescent lamp in the prismatic reflector shown in Fig. 38. The distribution of light is in marked contrast to that in Fig. 35, as this reflector is designed to throw an even illumination over a considerable area below it. This reflector comes down over the lamp, so as to protect the eyes from the glare of the bare filament when it is hanging pendant, even more than would the opal dome reflector, test on which has been

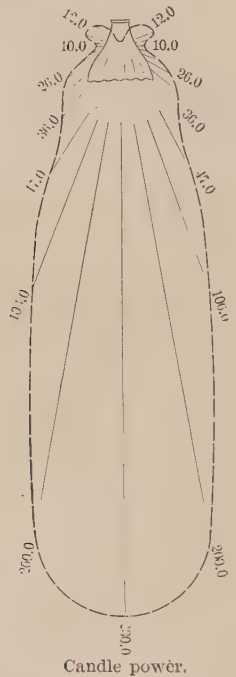


Fig. 35.—Light about a prismatic concentrating reflector.

shown in Fig. 21. The contrast between Figs. 35 and 37 makes it clear how important it is to select the proper reflector for a given piece of work. It would evidently be a great mistake to select the concentrating reflector shown in Fig. 35 for use on a chandelier where it is desired to make one or two lamps furnish general illumination for an entire small room. If this were done, the result would be very strong light immediately under the lamp if the lamp were in a pendant position (pointing straight

down), and the rest of the room would receive only a small amount of light. The reflector shown in Fig. 38 would throw the light evenly over the entire floor of a small room; but would not make a very intense light at any one place. It would, on the other hand, be a great mistake to put the reflector shown in Fig 37 at the top of a store window for lighting the goods in the window, or on a chandelier for reading purposes immediately under the chandelier.

Prismatic reflectors are also made which give a distribution of light which is a compromise between the concentration shown in Fig. 35 and the distribution shown in Fig. 37.

Fig. 39 shows the distribution of light about a 16-candle power incandescent lamp in the prismatic reflector shown in Fig. 40. This reflector is covered either with white cardboard or

FIG. 36.—Very concentrating prismatic reflector.

celluloid to prevent light from passing through as it is intended for desk use where it is placed within the ordinary range of vision.

Another incandescent lighting unit using prismatic glass reflectors is the new high efficiency graphitized filament Gem incandescent lamp. These are sold with substantial shade holders, which are designed to hold the shade in proper focus. They should always be used with such holders; otherwise they will not give the desired distribution. The lamps are usually equipped with frosted tip bulbs, as they give a very powerful light, and if some means of diffusion were not provided the blinding effect due to the glare of the filament would be very great.

The following tests, Figs. 41 to 48, were made on lamps of this type by Prof. H. E. Clifford, of Massachusetts Institute of Technology and reported to the National Electric Light Association in 1906.

Fig. 41 shows the light about a 125-watt clear bulb, double loop, graphitized filament, high efficiency, Gem incandescent lamp without reflector. The mean spherical candle power is 40.7, making the consumption per mean spherical candle power 3.1 watts.

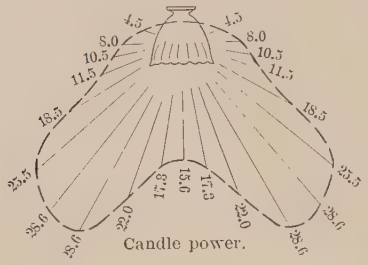


Fig. 37.—Light about a distributing prismatic reflector.

Fig. 38.—Prismatic bowl reflector.

Fig. 42 shows the light about a lamp of the same type frosted only on the tip. The loss due to frosting is about three per cent.

Fig. 43 shows the light about a clear bulb 125-watt lamp

Fig. 39.—Light about a prismatic desk shade.

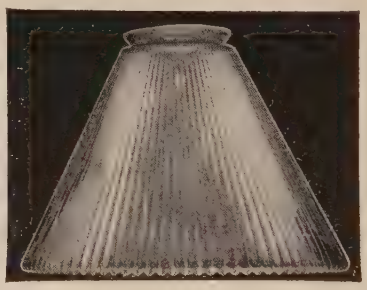


Fig. 40.—Prismatic desk shade without cardboard cover.

equipped with a prismatic reflector of the distributing type, shown in Fig. 44.

Fig. 45 shows the light distribution about the same lamp and reflector as in Fig. 44, except that the tip of the lamp is frosted.

Fig. 46 shows the light about a clear bulb lamp of the same

type equipped with a concentrating prismatic reflector shown in Fig. 47.

Fig. 35 shows the light about the same lamp and reflector as in Fig. 46, except that the tip of the lamp is frosted.

This type of lamp and reflector is undoubtedly suitable for a large number of cases, but care should be exercised in its use;

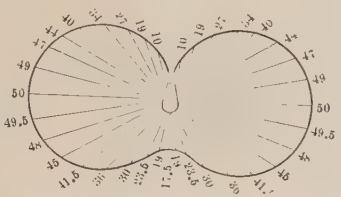


FIG. 41.—Light about a clear bulb 125 watt, Gem lamp.

one advantage of this type of lamp is that it can and should be placed close to the ceiling, where it is out of the ordinary range of vision, and yet give a good distribution of light for general lighting purposes. Thus, in the case of an office where simply general illumination is wanted and the lamp is placed at the ceiling, this would be suitable, although the desks would probably have to be lighted by their own individual lamps, because

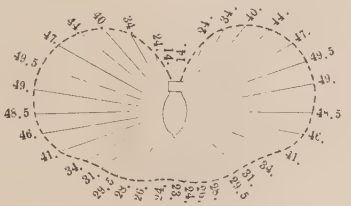


FIG. 42.—Light about a frosted tip 125 watt, Gem Lamp.

the writers would probably be directly in their own shadows. In the case of stores, halls, and similar places where a large volume of light is wanted this type can be used to good advantage to replace ordinary clusters wherever a larger unit than 16-candle power is desired. Owing to the high temperature at which they are operated they give a whiter light than the ordinary incandescent lamp. Their size calls for care in prevent-

ing the light from a bare filament striking the eye. Except where concealed they should be used with frosted tip.

Opaque Metal and Mirror Reflectors.

Fig. 49 gives the light distribution about a 16-candle power incandescent lamp with an eight-inch metal reflector painted white inside, the form of which is shown in Fig. 50. This is the

Fig. 43.—Light about a clear 125-watt Gem lamp with distributing reflector.

Fig. 44.—Gem lamp and distributing reflector.

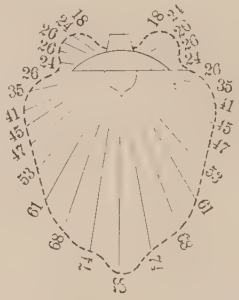


Fig. 45.—Light about frosted Gem 125 watt lamp with distributing reflector.

kind of reflector so often seen in workshops, draughting-rooms and offices. It is designed to concentrate considerable light below the lamp, and succeeds fairly well in this, as can be seen. For a space of ten degrees each side of the vertical, it gives over 36-candle power. Being of metal and entirely opaque, of course no light is thrown above the edges of the shade. The serious objection to such a shade as it stands is the extremely

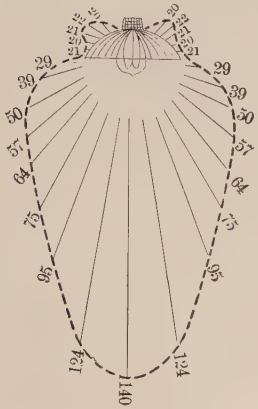


FIG. 46.—Light about clear bulb Gem 125-watt lamp with concentrating reflector.

FIG. 47.—Gem lamp and concentrating reflector.

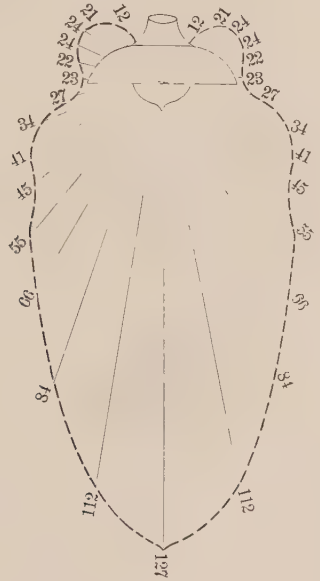


FIG. 48.—Light about a frosted tip Gem 125-watt lamp with concentrating reflector.

streaked light which it casts. In other words, it does not eliminate the streaks which are inherent in the incandescent lamp which is the source of light. Such a shade, if painted inside with aluminum paint, will give a well-diffused light,

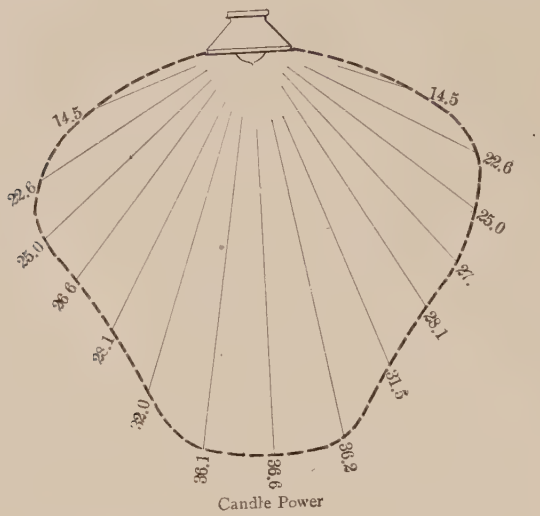


FIG. 49.—Light about a metal cone reflector.

practically free from streaks. Another way of getting over these streaks is to use a frosted bulb lamp. Although the authors have not secured tests on the relative efficiency of the reflector coated with white paint inside as against the reflector

FIG. 50.—Metal, 8-in. reflector.

coated with aluminum paint, some rough, practical trials have convinced them that there is not enough difference between the white paint and the aluminum paint to be worth considering as far as the amount of light is concerned, while the quality of the light from the aluminum paint is vastly superior because

of the freedom from streaks. These cheap metal reflectors are in very common use in draughting rooms and offices, where it is of great importance to the welfare of the users that they be not forced to strain their eyes with a streaked light of this kind. If the owners of such shades do not feel able to replace them with some of the more efficient types mentioned later, they can

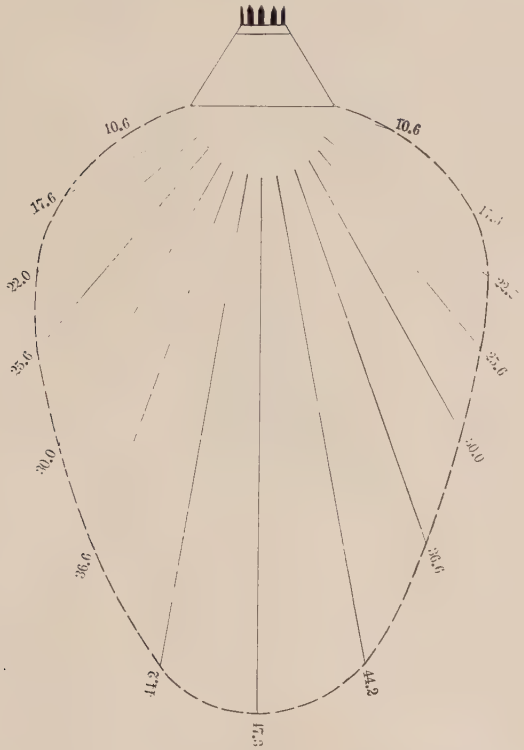


FIG. 51.—Light about an aluminum cone reflector.

at least afford to have them coated inside with aluminum paint.

Fig. 51 gives the light distribution about a 16-candle power incandescent lamp in an aluminum cone reflector with frosted aluminum finish inside. This reflector, which is shown in Fig. 52 is a fairly powerful concentrator giving about 47-candle power below the tip of the lamp. On the whole it is much preferable to the green opal reflector shown in Fig. 26, although

perhaps not as pleasing in appearance when lighted, as it is opaque. It gives a well diffused light free from streaks on account of its frosted reflecting surface. A point to be remembered in purchasing aluminum reflectors for office and draughting room use is that they should have a frosted rather than a polished aluminum surface. A polished surface will invariably give a streaked light, which is trying to the eyes if the light is perfectly stationary and still worse when the light swings or vibrates slightly. Besides its excellent light-reflecting qualities, the aluminum cone is very light and not easily broken. This fits it well for use on portable and adjustable fixtures in offices and shops. It should be considered along with other efficient opaque reflectors mentioned later.

Fig. 53 shows the distribution about a 16-candle power lamp equipped with the shade shown in Fig. 54. The light distri-

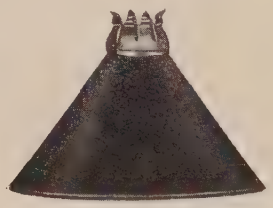


Fig. 52.—Aluminum cone reflector.

bution from a 32-candle power lamp with the same reflector is shown in Fig. 55. This is a shade with a corrugated mirror reflecting surface, the reflecting surface being applied under the paint which covers the outer surface. It has a tremendous concentrating power, giving over 108-candle power at the tip of the 16-candle power lamp. With a 32-candle power lamp, the maximum candle power covers a much larger angle than with the 16-candle power. Streaks of light which are likely to be present with mirror reflectors are in this case partially wiped out by the corrugations, so that, except when the work is very near the lamp, this reflector can be used without a frosted bulb lamp, although the latter is recommended. This reflector is an excellent one to use wherever good, powerful, concentrated light is desired, and where an opaque reflector is not objectionable. It is well suited to show-window lighting, office desk lighting

and billiard-table lighting wherever other lamps are present for the general illumination of a room. It is considerably more expensive, heavier and more likely to be injured than the

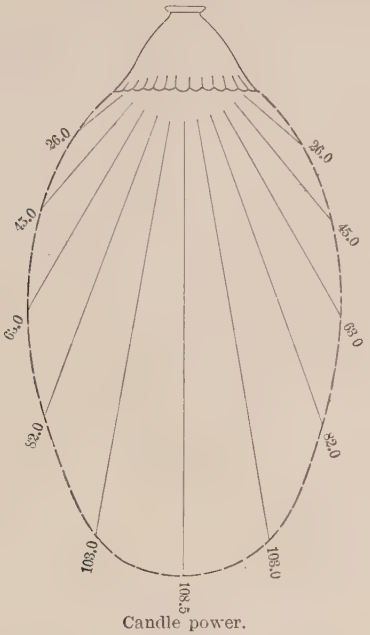


FIG. 53.—Light about a corrugated mirror reflector.

frosted aluminum cone, Fig. 52, but it gives a more powerful light and is more easily kept clean on account of its smooth inner surface.

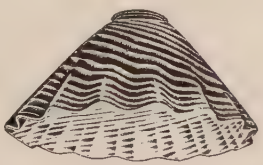


FIG. 54.—Corrugated mirror reflector.

Fig. 56 shows the light distribution about a seven-inch desk shade, shown in Fig. 57. This is a shade which has a silvered mirror reflecting surface, but instead of being open, as are most

reflectors, it has a ground-glass bottom through which the light must pass and which eliminates the streaks. It is, of course, intended to give a concentrating light for desk use and draughting. The maximum candle-power below the lamp is about 48. Its performance on the whole is very similar to that of the frosted aluminum cone, but this type of reflector has the advantage that no matter at what angle it may be placed, the bare lamp is not visible, as all the light comes through ground glass. For desk work, where it is almost always desirable to place the reflector at an angle, this is a good feature as the light

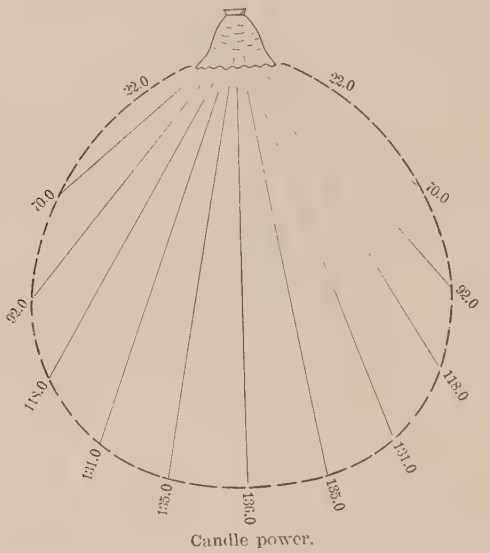


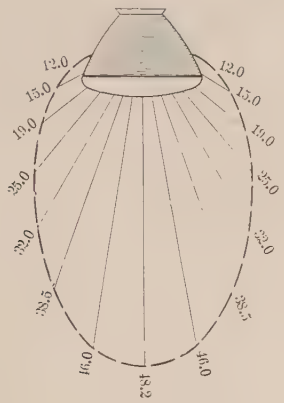
FIG. 55.—Light about corrugated mirror reflector with 32 c. p. lamp.

practically comes from the entire surface of the ground glass and the character of the light from it makes it more comfortable to work by than when an open reflector is used. This shade should never be used without a mica or asbestos gasket in the shade holder to prevent dirt collecting inside of the shade.

Another shade similar to the above has its reflecting surface opal with green backing like the common desk shade. It is, in fact, the common desk shade with a ground glass bottom. It is not subject to deterioration of the reflecting surface like

those which depend on mirrors for their reflecting value, but it does not give as strong a light as the others.

Fig. 58 shows the distribution of light in two planes about



Candle power.

FIG. 56.—Light about McCreary desk shade.

a 16-candle power incandescent lamp in a parabolic aluminum reflector with frosted aluminum finish inside. This reflector is shown in Fig. 59. The candle power in the vertical plane

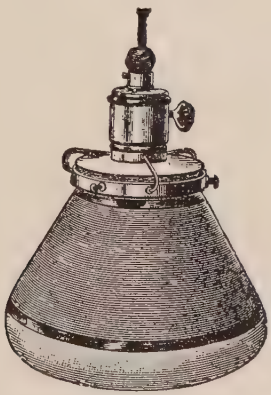


FIG. 57.—McCreary desk shade.

of the lamp axis is shown by the dotted lines, as in the other diagrams, while the candle power in a vertical plane at right angles to the lamp axis, technically known as normal to the

lamp axis, is indicated by a heavy line on the same diagram. This is a reflector which is coming into common use for desk and office work as well as for shops and all places where a light, easily adjusted, opaque reflector is needed. This test shows the re-

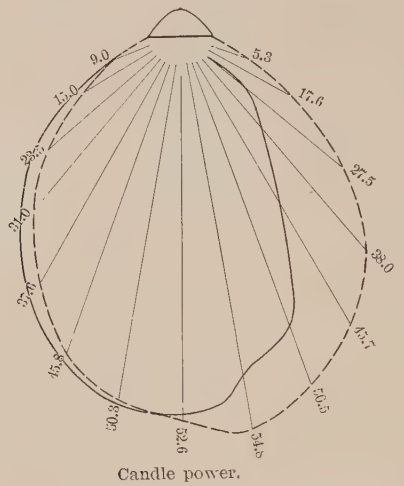


FIG. 58.—Light about parabolic aluminum reflector.

flector to be an excellent one for this purpose. It gives over 50-candle power at the angles where the light is most wanted in desk lighting, and gives over 40 candle power through an angle of about 70 degrees. The reflector is light and is usually

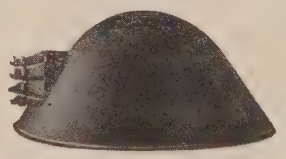


FIG. 59.—Parabolic aluminum reflector.

made so that it can be quickly turned at any desired angle. The easy way in which it can be adjusted, as well as the excellent distribution of light from this reflector, are strong points in its favor. Reflectors of this kind can be obtained with various outside finishes so that they will harmonize with almost any

surroundings. Not being patented articles, they are low in price. For most cases, the streaked light from the polished aluminum will be objectionable. Generally, the frosted aluminum finish is the one to be chosen and it is preferable to use a frosted lamp in it.

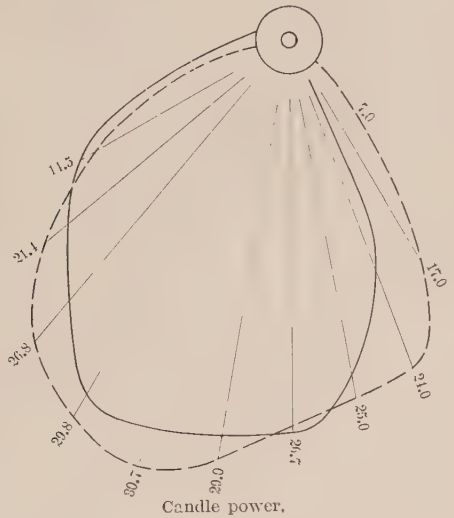


FIG. 60.—Light about cylindrical desk reflector.

Fig. 60 shows the distribution of light in two planes about a 16-candle power incandescent lamp placed in a cylindrical desk reflector with aluminum paint finish inside. This reflector is shown in Fig. 61. The solid lines show the light given in the

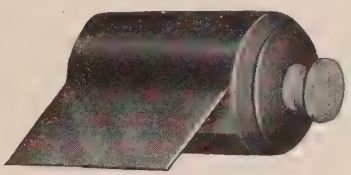


FIG. 61.—Cylindrical desk reflector.

plane of the lamp axis, while the dotted line shows the light given in the plane at right angles or normal to the lamp axis. Cylindrical desk shades of this kind are in common use, and may be compared with the parabolic shade shown in Figs.

58 and 59. The light obtained from the cylindrical desk shade is considerably less than from the parabolic reflector. Not only is the maximum candle power approximately half that of the parabolic shade, but it does not extend over as great an

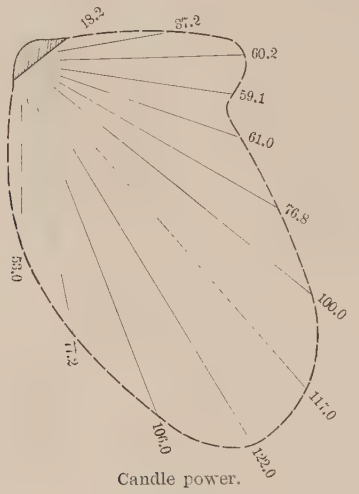


FIG. 62.—Light about a window trough reflector.

angle. The cylindrical form of shade with aluminum paint finish is, however, much to be preferred to the same shade with white paint finish, as the latter causes streaks in the light which are extremely objectionable and necessitate the use of frosted lamps.

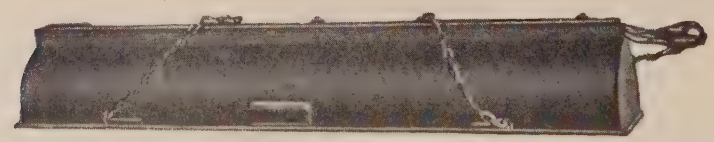


FIG. 63.—Window trough reflector.

Fig. 62 shows the distribution of light about a trough reflector, shown in Fig. 63, with two lamps of 16-candle power. The reflecting surfaces are glass mirrors. Such trough reflectors are made for store window lighting purposes, being placed at

the top of the window out of sight from the street. Fig. 62 shows the light on a vertical plane normal or at right angles to the reflector. This can be compared with the light thrown from the reflector shown in Figs. 55 and 72. Both of these types of reflectors are much used for window lighting. The conical

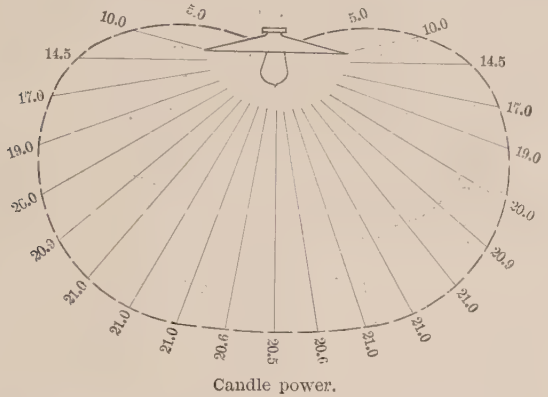


FIG. 64.—Light about an 8-in. flat metal reflector.

reflector has much the best of it in this test for the majority of windows.

For the average small window the reflector shown in Figs. 35 and 36 is to be preferred to Fig. 63, because of its higher candle power at desirable angles and greater durability. The

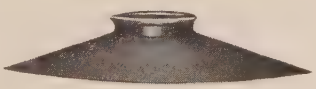


FIG. 65.—Flat enameled metal reflector.

reflector shown in Fig. 72 gives an even greater amount of light at desirable angles, although more subject to deterioration.

Fig. 64 gives the light distribution about a 16-candle power incandescent lamp with an eight-inch flat metal reflector painted white inside, shown in Fig. 65. This is similar to the light obtained from the flat opal reflector in Fig. 27, and the suggestions made with reference to that apply equally here.

Fig. 66 shows the distribution of light about a six-inch ornamental mirror reflector illustrated in Fig. 67. This gives a candle power of from 20 to 30 at the most useful angles below the horizontal. The principal application of this reflector is in connection with clusters and on ceilings where the fact that the reflector is opaque is not a drawback. It is sometimes used by mistake where the more concentrating type of mirror reflector, shown in Fig. 54, should be used. The use of this or any other reflector on a chandelier or cluster at an angle and hung low enough to be in the ordinary line of vision is objectionable on

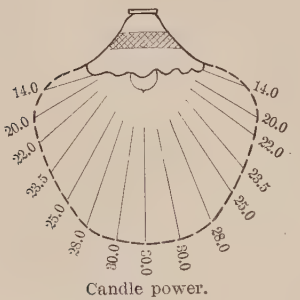


Fig. 66.—Light about an ornamental mirror reflector.

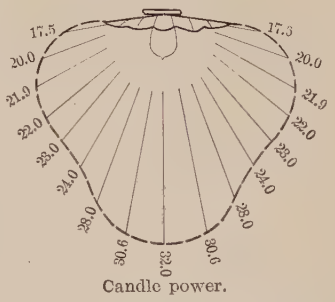


Fig. 68.—Light about a flat corrugated mirror reflector.

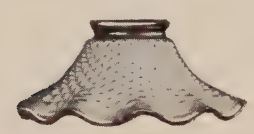


Fig. 67.—Ornamental mirror reflector.

Fig. 69.—Flat corrugated mirror reflector.

account of the glare received in the eyes. The remedy is the use of frosted bulbs or the placing of the cluster high.

Fig. 68 shows the distribution of light about a 16-candle power incandescent lamp in a ten-inch flat fluted mirror reflector, shown in Fig. 69. Although a reflector of this form would naturally be expected to give a rather wide distribution of light below the horizontal, it will be seen that the candle power directly below the lamp is considerably higher than with other flat reflectors shown in this series of tests, while the candle power a little below the horizontal is nearly as great as with

some of the other flat reflectors. The proper place to use a reflector of this kind is where it is desirable to illuminate a considerable area and at the same time to obtain much light immediately under the reflector. Like all opaque reflectors

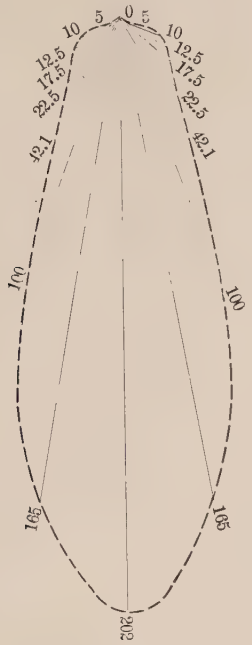


FIG. 70.—Light about a 10-in. mirrored cone reflector with 16 c.p. lamp.

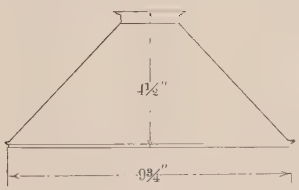


FIG. 71.—Ten inch mirrored cone reflector.

it cannot be used where darkening of the ceiling is objectionable.

Fig. 70 shows the distribution of light about a 16-candle power lamp in a metal cone reflector with plate mirrors for reflecting surface. The reflector is shown in Fig. 71.

Fig. 72 shows the light about the same reflector with a 32-candle power lamp. These are the most powerful of the concentrating reflectors when new.

Frosted Reflectors.

Reflectors of frosted, roughed or sand-blasted glass are not common, though some of the effects of a reflector are sometimes obtained with common bell-shaped shades as explained later.

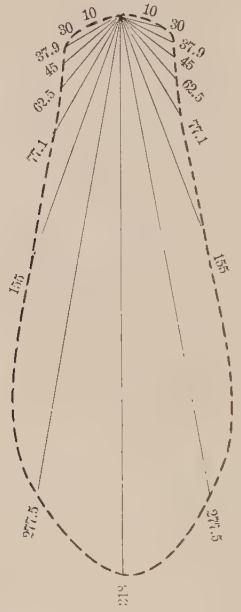


Fig. 72.—Light about a 10-in. mirrored cone reflector with 32 c.p. lamp.

Sand-blasted domes are used occasionally, and a test on one with a 16-candle power lamp, sand-blasted inside is shown in Fig. 73. This is of the same general shape as the seven-inch opal dome shown in Fig. 22, except that it is 3.25 inches instead of 3.75 inches in depth. It does not alter the distribution of light from the lamp as much as the opal dome, although somewhat more pleasing in appearance because of the diffused light which shows through it.

Enclosing Globes.

Fig. 74 gives the light distribution about a 16-candle power incandescent lamp placed in a glass ball six inches in diameter, sand blasted on the inside. This ball is shown in Fig. 75 Sand-blasted globes of this kind are very common at the present time. It will be seen that the distribution of light is not altered materially from that of the bare incandescent lamp. Such a sand-blasted globe is of considerable value in diffusing the light, as mentioned in a paragraph on the frosted bulb incandescent lamp. In practice, when such a bulb is put in a pendant position on a chandelier or fixture, the open space at its neck should be closed with an asbestos gasket, to prevent dirt collecting in the globe. If used in an upright position the gasket can be omitted.

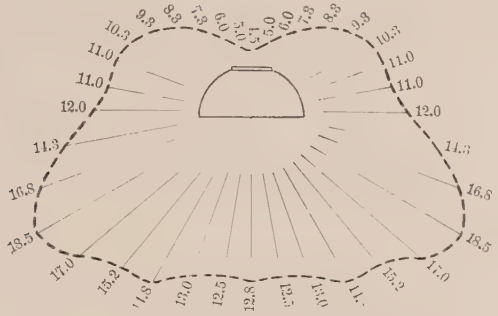


Fig. 73.—Light about a sand blasted dome.

Fig. 76 shows the distribution of light about a 16-candle power lamp enclosed in a pressed glass stalactite globe shown in Fig. 77, This globe absorbs considerable light, and does not alter the direction of the rays materially. The absorption or loss of light in passing through the thick glass of the stalactite amounts approximately to 25 per cent. This is another example of a globe which is purely ornamental and of very little use as diffuser of light. The glare of the filament received through a globe of this kind is much more than would be received through a frosted globe or bulb or a Holophane globe either one of which absorbs less light.

The globes known as Holophane are designed with two objects in view. One of these objects is to redirect the rays of light,

thus accomplishing some of the things accomplished by a reflector in taking light which would otherwise be useless and directing it in useful directions. This redirecting of the light rays as they pass through the globe is accomplished by reflection and refraction of the rays by means of prisms pressed on the outer surface of the globe. They are made in three

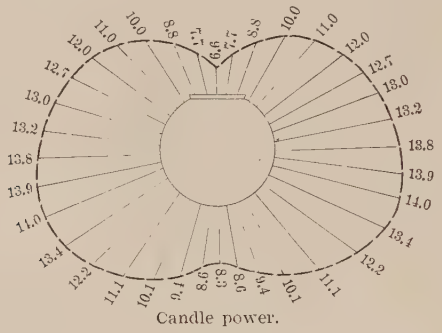


FIG. 74.—Light about a sand blasted ball.

classes. Class A globes concentrate light immediately under the lamp. Class B globes give a general distribution below the horizontal. Class C globes give the most light at a little below the horizontal. The other object accomplished by this type of globe is the diffusion of light to avoid the glare of the arc, incandescent filament, Nernst glower or gas flame, as the case

FIG. 75.—Six inch sand blasted ball.

may be. That is, it accomplishes the same thing as the frosted bulb or globe only to a much greater degree. The rays of light are broken up by prisms on the inside of the globe so that the eye does not meet the direct light from the filament of the lamp. The rays are so successfully broken by passing through these inner prisms that the whole globe appears to glow with a

mild light. The light, therefore, instead of coming from a small, intensely lighted filament, comes from the whole surface of the globe. This reduces materially the blinding effect which has been spoken of frequently before, and enables a person to see better because the pupil or iris of the eye is not contracted to such an

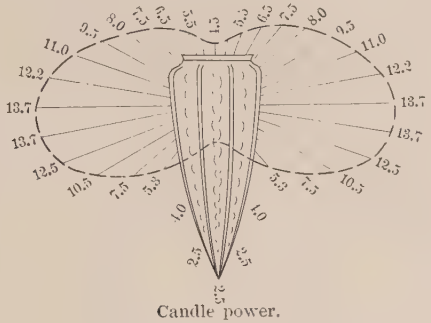


FIG. 76.—Light about a pressed glass stalactite.

extent in an involuntary effort to shut out the intense blinding light. The absorption or loss of light in passing through Holophane globes is remarkably low considering what they accomplish. Probably the most extensive tests ever made on this glassware were conducted by Professor W. L. Smith of the

FIG. 77.—Pressed glass stalactite.

Massachusetts Institute of Technology, who found that the loss of light by absorption in this type of globe amounted to from 10.0 to 16.8 per cent. with an average of 12.3 per cent. On account of the deep corrugations which form the prisms on these globes, unnoticed dirt is likely to collect on them and

they should be brushed off at frequent intervals with a dry, stiff brush, brushing lengthwise of the prisms. At longer intervals they should be taken down and scrubbed with a brush in soap and water. Like all other enclosed globes, the opening

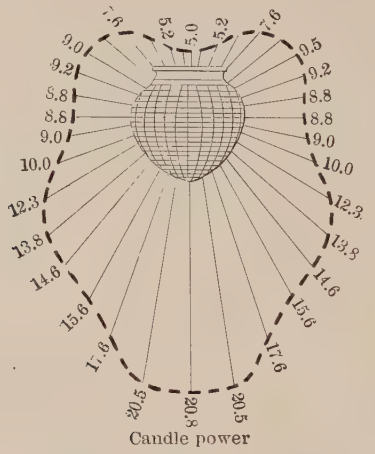


FIG. 78.—Light about a Holophane Class A Stalactite.

around the shade holder should be filled with a mica or asbestos gasket to keep out dirt. The amount of light likely to be absorbed by the collection of dust on the prisms is not as great

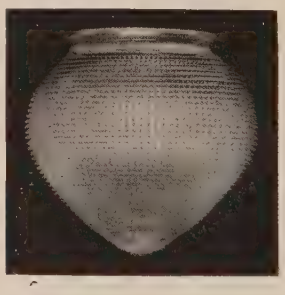


FIG. 79.—Holophane Class A Stalactite.

as might be anticipated, amounting in one test made at the Electrical Testing Laboratories with a Holophane globe thickly coated with dust, to about 13 per cent.

Fig. 78 shows the distribution of light about a 16-candle power

incandescent lamp enclosed in a Holophane globe shown in Fig. 79. As seen from the test, this globe is one designed to direct the rays of light so as to give a maximum candle power immediately under the lamp. For a distance of 10 degrees each side of the vertical, the candle power is over 20. This is, of course, much less than is obtained with most types of reflectors, and for this reason a globe of this pattern is not to be recommended where a large amount of downward light is wanted unless a diffusing globe is necessary. There are many locations, however, where it is necessary to use a diffusing globe in order to avoid the glare of the bare filament, and at the same time to direct the light in downward directions. The principal application of this globe is on chandeliers for the general lighting of rooms where the sockets on the chandeliers are placed at an angle of 45 degrees as is very common. On such a chandelier this globe will throw the light down into the various parts of the room instead of letting it escape toward the ceiling, and it will, at the same time, do away entirely with the glare from bare lamp filaments. Were reflectors of any kind used for this same purpose, frosted bulb lamps would be necessary and the diffusion or softening of the light could not be as well accomplished as with the Holophane globe. This type of globe, which is designed to give a concentrated downward light, should not be used on a chandelier having the sockets pointed straight down if the general lighting of the room is the thing desired; but if it is desired to create a light space for reading immediately under the chandelier and at the same time obtain a fairly good light in other parts of the room, use of these globes on downward pointed sockets will give good results. It is also good for studded lights on ceilings.

Fig. 80 gives the distribution of light about a 16-candle power incandescent lamp enclosed in a Holophane globe the general shape of which is that shown in Fig. 81, the only difference between this and Fig. 79 being in the angles of the prisms and the size. This is the smaller of the two globes. This type is designed to distribute light in all directions below the horizontal, giving a good general illumination of a room when placed in a pendant position.

Fig. 82 shows the distribution of light about a 16-candle power incandescent lamp enclosed in a spherical pendant Holophane

globe, 5.5 inches in diameter, shown in Fig. 83. In this case the light below the horizontal is not greatly increased as compared to the bare lamp except immediately below the lamp. Aside from this increase in candle power immediately below the lamp, the principal effect of this particular globe is to

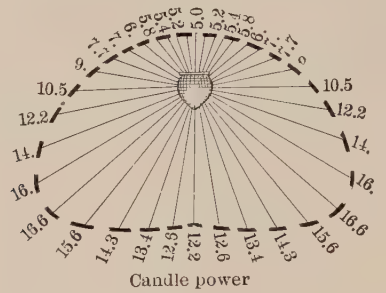


FIG. 80.—Light about a Holophane Class B Stalactite.

diffuse and soften the light. It can be compared to the distribution of light around the ground glass ball which is also a good diffuser and softener of light.

Fig. 84 gives the distribution of light about a 16-candle power incandescent lamp enclosed in a Holophane spherical globe,

FIG. 81.—Holophane Class B Stalactite.

placed upright, shown in Fig. 85. This should be compared with the illumination obtained from a bare incandescent lamp placed upright, also from an incandescent lamp enclosed in the various diffusing globes before shown. The distribution of light from lamps and globes placed upright can, of course, be

easily obtained by inverting any of the diagrams before given. This globe offers a valuable means of increasing the illumination in downward directions from all kinds of fixtures where the incandescent lamps are placed upright. The majority of bell-

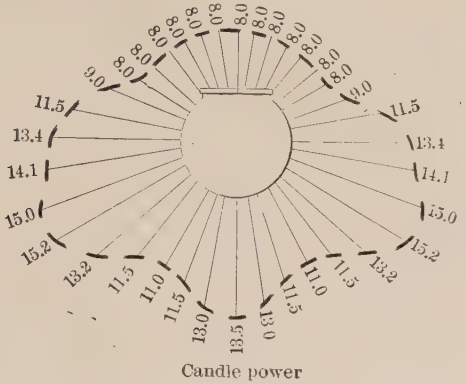


FIG. 82.—Light about a Holophane Class B Ball.

shaped shades when placed on such upright fixtures have the effect of robbing the lower part of the room of light and throwing even more light toward the ceiling than would be there if the lamp were bare. This globe distributes the light below the

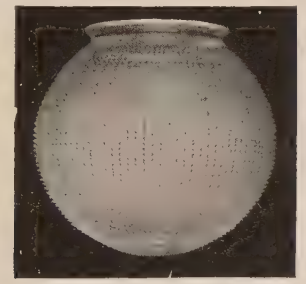


FIG. 83.—Holophane Class B Ball.

horizontal in such a way as to give a fairly even illumination all over the lower part of a small room.

The prisms in Holophane globes have to be calculated and the molds cut accurately and a good grade of glass employed. Otherwise the absorption of light by the glass is very high and no useful

change made in the distribution of the light. This is well shown by Fig. 86, which is from a test made with a 16-candle power lamp in the stalactite globe shown in Fig. 87. The globe resembles closely some with calculated prisms, but absorbs a much greater amount of light. It also has little or no value in re-

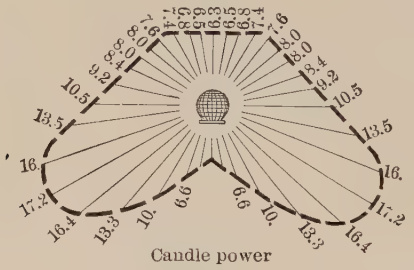


FIG. 84.—Light about a Holophane Upright Class B Ball.

directing the light in useful directions and does not give the same diffusion as a globe with accurately cut prisms.

Fig. 88 shows the distribution of light around a prismatic reflecting glass ball, the top of which is formed into a prismatic reflector, as shown in Fig. 89. The bottom is plain frosted glass. This ball combines in one the characteristics of a diffusing

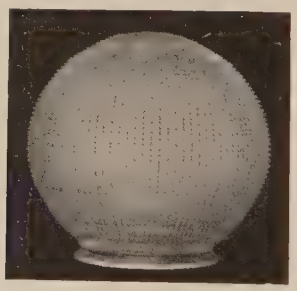


FIG. 85.—Holophane Upright Class B Ball.

globe and reflector. The distribution of light from such balls can be varied by varying the position of the lamp inside of the ball. The lower the lamp is placed the wider the distribution.

It will be seen from the foregoing that not every globe that has prisms on it is to be considered as a true prismatic globe.

Such globes should not be selected on appearance but rather from photometric tests which show just what light distributions they give. In the absence of such tests or their equivalent one is working absolutely in the dark.

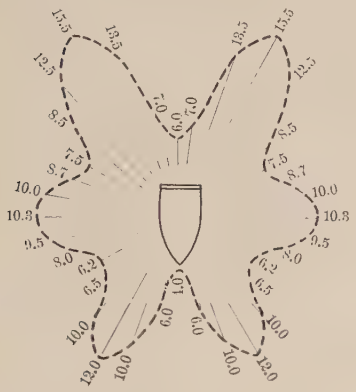


FIG. 86.—Light about an uncalculated prismatic stalactite.

FIG. 87.—Uncalculated prismatic stalactite.

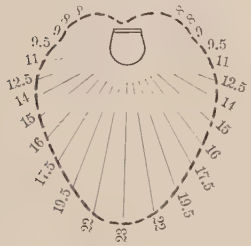


FIG. 88.—Light about a prismatic reflecting ball.

FIG. 89.—Prismatic reflecting ball.

OPEN SHADES.

Fig. 90 gives the light distribution of a 16-candle power incandescent lamp in an ornamental glass bell-shaped shade or reflector, the form of which is shown in Fig. 91. This reflector is of a very common shape. The outside is lightly frosted and the ornamentation is cut into it. It is seen that this glass bell causes some increase in the candle power in downward directions and a decrease in horizontal directions. While it makes some

improvement over the distribution of light from the bare lamp it does not make any such marked change as do the reflectors shown in Figs. 22 and 24. A reflector of this bell type is usually chosen simply as a matter of ornament, without any attempt to redirect the rays of light. This particular reflector probably changes the natural distribution of light from the lamp more

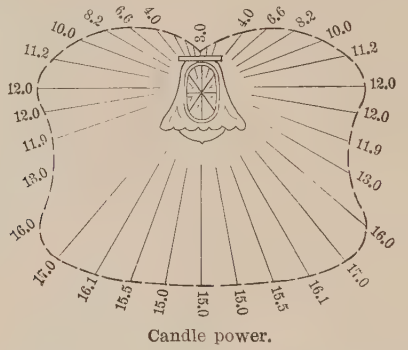


FIG. 90.—Light about an ornamental frosted shade.

than would many others of the same general shape, because of the frosting on its outside, which tends to make the bell mouth a reflector. Frequently a glass bell such as this is used on a bracket or chandelier in an upright position. In such a case it is evident that instead of adding to the useful downward

FIG. 91.—Ornamental frosted shade.

light, it detracts considerably from it and throws much light towards the ceiling.

Fig. 92 shows the light about the shade shown in Fig. 93 with a 16-candle power incandescent lamp. This shade was roughed or sand-blasted on the inside. Its general characteristics as to light distribution are very similar to those of Fig. 90.

It would be useless to report here on many tests with this general type of bell shade, as they are made in such immense variety, and designs change from year to year. They must always be considered mainly as ornamental, as they usually absorb and waste considerable light, and are as a rule of little value in

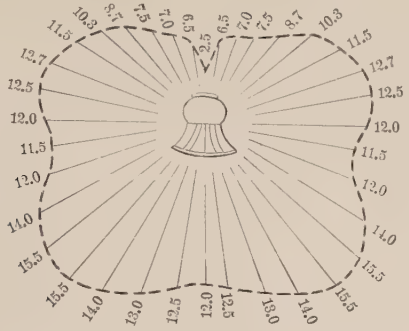


FIG. 92.—Light about a glass shade roughed inside.

redirecting the light rays. For locations where expense is no consideration globes of this kind can be freely used. It in nevertheless, true that by certain changes in shape and desigo much of the glassware now manufactured purely for decorativn purposes might be made useful as well, and on the other hand some of the staple glassware which is now to be considered as

FIG. 93.—Glass shade roughed inside.

mainly useful rather than ornamental could be made ornamental as well. The manufacturers of unpatented types of glassware might well give attention to these matters.

Fig. 94 shows the distribution of light about a 16-candle power incandescent lamp placed in a Holophane open shade, designed for use as a pendant, and shown in Fig. 95. As seen

from the test, this globe is of the type which increases the illumination in downward directions. When such a shade is used on a chandelier, it should be placed on sockets which are pointing straight down or at an angle of not greater than 30 degrees from

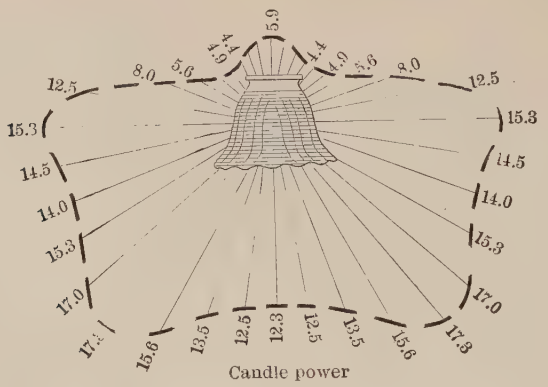


FIG. 94.—Light about a Holophane Class B Pendant Shade.

the vertical, as otherwise it will not only throw more light up than is necessary but will expose the glaring lamp filament. Where used at an angle frosted tipped lamps should be employed.

Fig. 96 shows the distribution of light about a 16-candle power upright incandescent lamp in a Holophane open shade

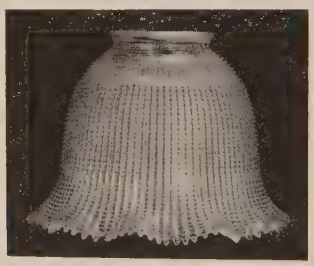


FIG. 95.—Holophane Class B Pendant Shade.

shown in Fig. 97. This shade is mainly useful as a diffuser, although it increases the useful illumination immediately below the lamp.

Fig. 98 shows the distribution of light about a 16-candle power incandescent lamp upright in a Holophane open shade,

shown in Fig. 99. This shade is designed to make a marked increase in the illumination immediately below the lamp, in which it succeeds very well, as within a narrow angle below the

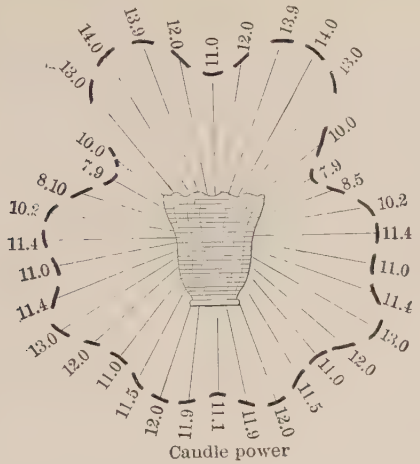


FIG. 96.—Light about a Holophane Class B Upright shade.

lamp it gives about 20 candle power. This shade can be used to advantage where it is desired to secure good light for reading or writing under chandeliers or brackets equipped with upright incandescent lamps.

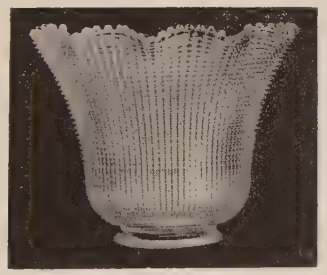


FIG. 97.—Holophane Class B Upright shade.

Fig. 100 shows the distribution of light around a 16-candle power incandescent lamp, placed in a combination Holophane diffusing and reflecting shade shown in Fig. 101. It is designed

specially for use on wall bracket fixtures. This globe consists of a prismatic reflector on one side and a Holophane globe on the other, the two features being combined in the one globe. In the use of such globes it is manifestly advisable to take

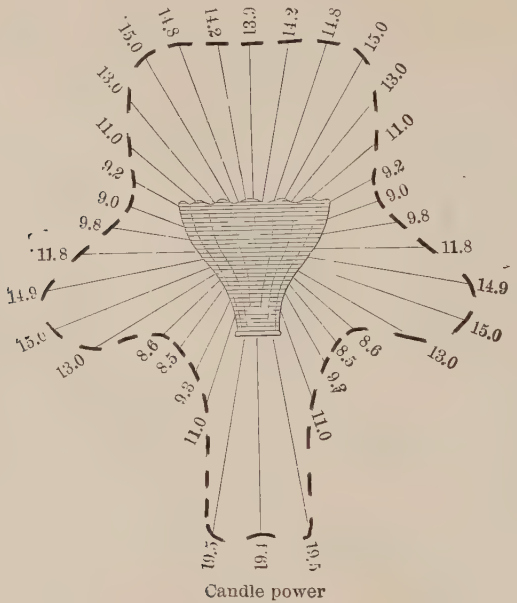


FIG. 98.—Light about a Holophane Class A Upright Shade.

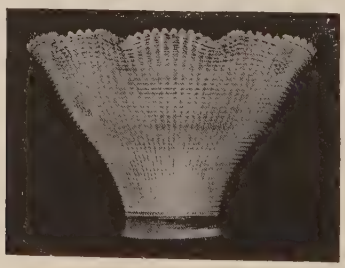


FIG. 99.—Holophane Class A Upright Shade.

unusual precautions to prevent their being turned around so as to throw the maximum light toward the wall instead of away from it. This globe makes a decided increase in the amount of illumination thrown away from the wall, if properly used.

Life of Frosted Lamps.

During the last few years there has rightly been a tendency in incandescent lighting to lower the intensity of the source of light, either by using enclosed diffusing globes or else by frosting the lamp bulb itself. The diffusion obtained by these methods has not only resulted in more artistic effects, but has also made the light much easier on the eyes. In this connection the ques-

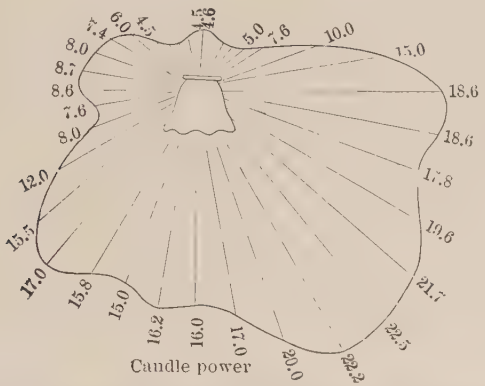


Fig. 100. –Light about a Holophane diffusing and reflecting shade.

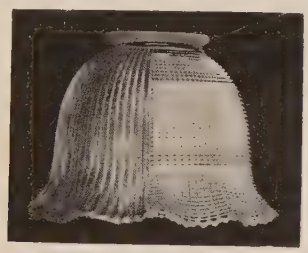


Fig. 101.—Holophane diffusing and reflecting shade.

tion has arisen as to the relative efficiency of the two available methods, which are:

1. Frosting the lamps themselves and using them without enclosing globes.

2. The use of the bare lamp with a diffusing enclosing globe, either ground glass, opal, Holophane or other types.

It has generally been conceded that a frosted lamp, as far

as efficiency is concerned, is more economical than a plain lamp with a diffusing globe. Generally speaking, the absorption by such frosting is in the neighborhood of 10 per cent., while with the use of ground glass, and other types of diffusing globes, the absorption runs from as high as 75 per cent. down to about 12 per cent.

The authors have advocated the use of some sort of cover or gasket for the neck of an enclosing globe, such a cover being formed of asbestos, mica or some similar material which will keep out all dust and, in the case of white asbestos, increase the light below the horizontal. In order to determine the effect on the life of the lamp, with these various conditions, tests were made at the Electrical Testing Laboratories on the following:

1. Frosted lamp, bare.
2. Clear lamp and diffusing globe.
3. Clear lamp, diffusing globe and asbestos cover.

Ten lamps were taken for each test. The enclosing globes used were of the Holophane type, being spheres, 6.5 inches in diameter, with 3.25-inch holders. Ten of these were used without any cover, while ten others were protected with an asbestos disk or washer which practically prevented any dust from entering.

The loss of light due to the frosting of the lamps averaged nine per cent., while the loss due to the absorption of the globes was about 16.5 per cent.

When, however, the question of life is considered, it is found that the life with a frosted lamp is only 216 hours, whereas the globe under test gives 428 hours, or nearly twice the life. If the average mean spherical candle power is multiplied by the number of hours of useful life, it is found, in the first case, that the life is 2,383 candle hours with frosted lamps, while in the second place it is 4,401 candle hours, an increase of 85 per cent. Care should be taken not to confuse this with horizontal candle hours commonly used in considering the life of incandescent lamps.

Coming now to the question of asbestos disks in the neck of enclosing globes, we find that the total flux of light is practically the same in either case, but that the light in the lower hemisphere is increased about two per cent., and that the loss of life, due to the disks is about one per cent. Inasmuch as

there is a great gain due to the fact that dust is prevented from falling on the inside of the globe, and also on the lamp itself, it is beyond question a desirable thing to equip all pendant enclosing globes with some form of cover to prevent the collection of dust or dirt. Dirt collecting in the bottom of a diffusing globe is not only a cause of loss of light, but is inartistic and slovenly. It shows much more plainly in a diffusing globe than in any other and should be avoided both on account of the efficiency and appearance.

The object of frosting lamps is to cut down the intense glare of the bare filament with the least possible loss of light, rendering the lamp more agreeable to the eye and giving a more artistic effect. In many instances, the same results can be obtained by the use of ground glass diffusing globes with a corresponding increase in the life of the lamp. Where a reflector is needed and at the same time diffusion of the light from the lamp filament is advisable, a frosted bulb lamp is still the most easily available device for securing diffusion.

The usual guaranteed life of bare lamps of this kind with clear glass bulbs is 450 hours. The loss of life by enclosing them in globes is, therefore, about 5.5 per cent., while the loss of life by frosting is about 52 per cent.

The authors have the results of a large number of tests on the loss of light by absorption by different globes. These tests show such a lack of consistency that they have not been given here since the distribution of light with a shade or reflector is information of much more practical value than the total absorption. When such figures are given they are in general only approximate.

CHAPTER VI.

INDIVIDUAL GAS BURNERS AND THEIR REFLECTORS, SHADES AND GLOBES.

Before considering the question of light distribution obtained from different forms of gas lighting appliances it will be well to review briefly some of the difficulties which attend the subject.

In making any of the tests one of the primary considerations is to know the quality of the gas used. This is of most importance when open flame burners are employed, but it is also of importance with mantle burners. Naturally it was impossible to show tests on different qualities of gas, so the uniform practice was observed of having all the tests given herein made on New York City gas.

Another variable is the gas pressure. As will be seen from the curve in Fig. 102 the candle power of a mantle burner increases quite rapidly with an increase in pressure. It should be noted in this test, and also in the two following, shown in Figs. 103 and 104, that the burner was in every case adjusted for maximum incandescence. Fig. 103 shows that the candle power increases with the gas consumed nearly at the same rate as the pressure increases. Fig. 104 shows that the consumption and the pressure increase practically at the same rate and that, therefore (at least in this series of tests, which were very carefully made), when the mantle is adjusted for maximum incandescence the efficiency of the burner, that is to say, the candle power per cubic foot of gas, is very nearly independent of the pressure.

Among other variables may be mentioned different kinds of burners, the effect of different kinds and lengths of chimneys, quality and size of mantles, adjustment of mantles to have them incandesce equally on all sides, effect of side rod or center supports, etc. It is therefore manifest that in order to arrive at absolute values all of the above factors should be known.

In the following tests on mantle burners the pressure and consumption are stated and in the appendix trade data on all tests are given.

What the authors have aimed at is to get as near as possible to conditions as they actually exist in commercial work. Thus, although the pressures given are possibly below the average throughout the country, they give the actual conditions as they exist in New York City to-day. On the other hand, the tests probably show up better than would exist ordinarily, inasmuch

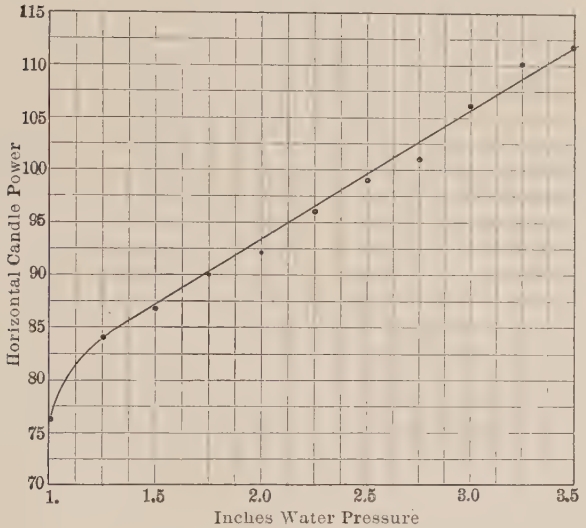


FIG. 102.—Variation of candle power with pressure.

as they were all made in a laboratory with ideal conditions as regards constant pressure, consumption, adjustment, cleanliness, new burners, mantles, glassware, etc. All told, then, the tests are probably fairly representative of what may be expected when gas appliances are properly cared for, and are in excess of what often happens in commercial practice.

With regard to open flame burners, Prof. C. P. Matthews* calls attention to the fact that, as the result of a number of tests on tips supposed to range from one to four cubic feet of gas per

*Proceedings National Electrical Light Association, May, 1903.

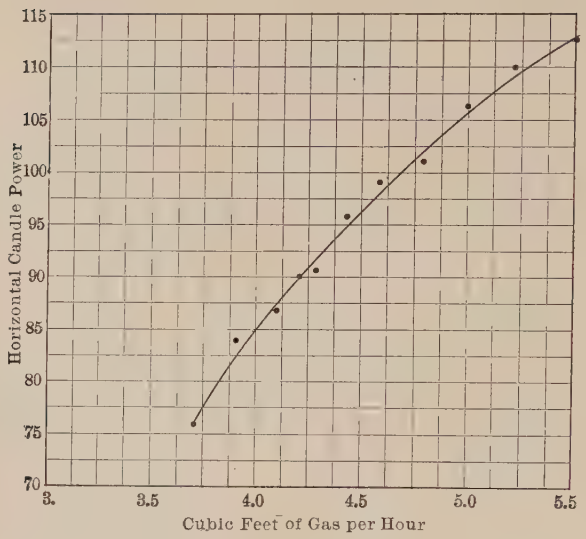


FIG. 103.—Variation of candle power with consumption.

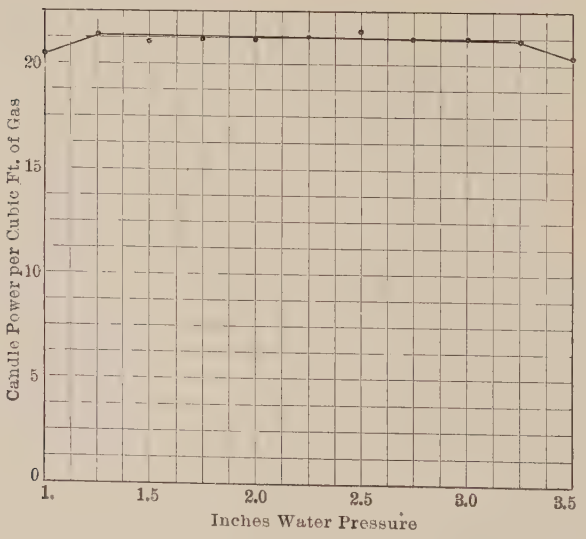


FIG. 104.—Variation of candle power per cu. ft. with pressure.

hour, in some cases a one-foot tip gave as high a candle power as a four-foot tip with no greater gas consumption. So great are the variations that apparently the nominal ratings of tips are practically valueless.

The introductory remarks of Chapter V, with reference to the necessity of studying the distribution of any light source in conjunction with its reflecting globe or shade should be carefully noted here, especially by those who have not read the previous chapter.

Open Gas Flames.

The first thing one notices in studying the distribution of light about an open flame burner is the remarkable fact that the flame gives very nearly the same amount of light whether

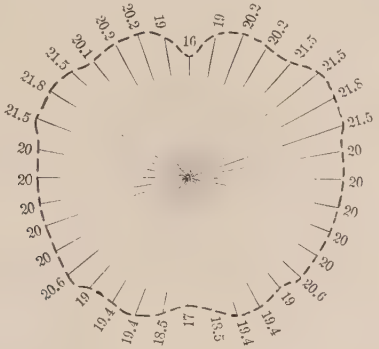


Fig. 105.—Open gas-horizontal distribution.

viewed either in the plane of the flame or at right angles to it. This is probably due to the fact that the hot particles of carbon do not greatly tend to screen the light from each other, although there is a slight tendency that way.

In Fig. 105 is shown the horizontal distribution curve of a flat flame burner consuming five cubic feet of gas per hour at a pressure equal to that of a column of one inch of water. This curve is made by measuring the candle power of the flame when viewed from different angles but all taken in the same horizontal plane.

Fig. 106 shows the distribution in a vertical plane about the same open gas jet as shown in Fig. 105. The mean spherical candle power is 21. This was the gas jet used in making all the

following tests on open gas flame shades. It will be noticed that the distribution of light is remarkably uniform in all directions with the exception of directly underneath where a

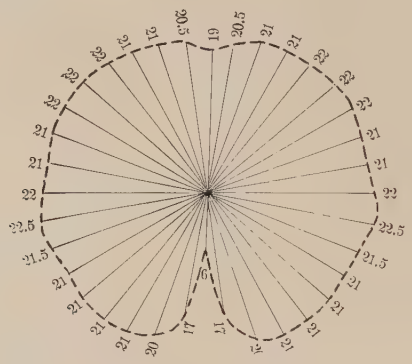


Fig. 106.—Open gas-vertical distribution.

small shadow is made by the pillar and the tip. As in the case of the mantle burner shown later practically one-half of the light is above and one-half below the horizontal.

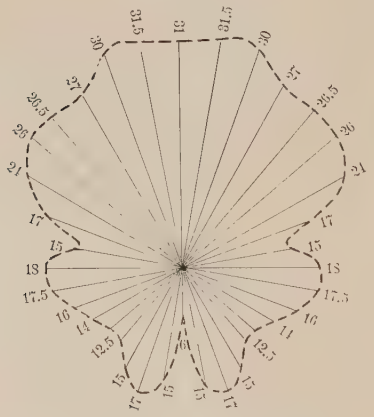


Fig. 107.—Light about an open gas etched globe.

Fig. 108.—Etched globe for open gas.

Fig. 107 shows the distribution of light about an etched glass globe, shown in Fig. 108, representing perhaps the great majority of open flame globes. The gas consumption was five cubic feet per hour at a pressure equal to that of a one-inch column

of water. It should be noticed that a large amount of the light is thrown upward, the globe acting somewhat as a reflector, there being a decrease of 30 per cent. below the horizontal as compared with the bare flame.

The real efficiency of a globe should not be measured, generally speaking, by the amount of light it gives forth, but rather by the amount of light which it throws below the horizontal, or in some particular direction where the light is wanted. Thus in the case of the globe shown in Fig. 107, although its absorption

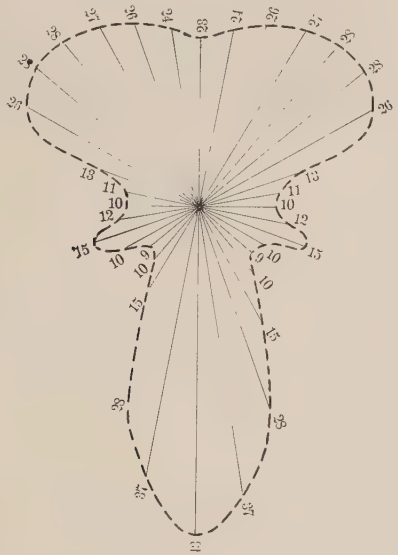


FIG. 109.—Light about an open gas Class A Holophane globe.

is comparatively small, the loss of light below the horizontal is rather large, and as this is the light which is generally used, it is seen that efforts to obtain an artistic effect and at the same time shield the eyes, succeed at a considerable loss of effective illumination.

It should also be noted that in the case of open flame burners, the necessity for diffusion is not nearly as great as with mantle burners, as both the intensity and quantity of light are low.

Fig. 109 shows the light about a Class A Holophane globe, shown in Fig. 110, designed to diffuse the light and at the

same time throw a strong light downward. Its absorption is about the same as the other open gas globes but its distribution curve is entirely different.

It is also possible to enclose the open flame gas jet in opal dome reflectors similar to those used on electric incandescent lamps. The relative distribution of light with such opal dome

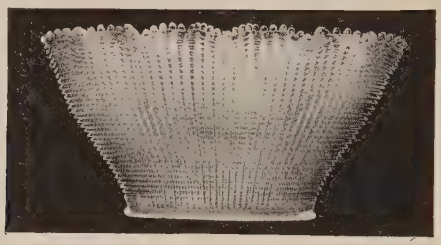


FIG. 110.—Open gas Class A Holophane globe.

reflectors will be similar to that obtained with incandescent electric lamps as given in a previous test.

INDIVIDUAL MANTLE BURNERS.

Fig. 111 shows the distribution of light about a bare upright mantle burner consuming 3 7 cubic feet of gas per hour at a pressure equal to that due to a water column of 1.6 inches. The

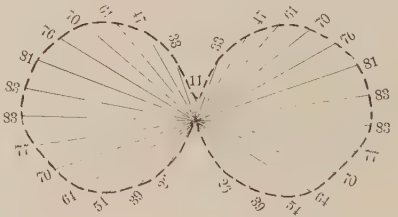


FIG. 111.—Light about a bare upright gas mantle burner.

mean spherical candle power is 63. Fifty-five per cent. of the light is above the horizontal and 45 per cent. below. It is therefore evident that for economical lighting as well as for artistic reasons it is inadvisable to use bare mantles in this way. There is a noticeable lack of light directly under and near the burner due to the shadow cast by the burner itself.

Fig. 112 shows the curve of the same burner under identical

conditions to those in Fig. 111 but equipped with a flat fluted porcelain reflector shown in Fig. 113.

While such a shade does not hide the bare mantle and therefore does not aid in the diffusion, it does give an increase of light at all angles below the horizontal and as such, is to be preferred to the bare mantle.

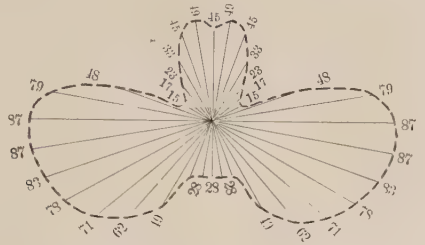


FIG. 112.—Light about a mantle burner with 8-in. fluted opal reflector.

Fig. 114 shows the distribution of light about the common air hole or opal *Q* globe shown in Fig. 115, the lamp burning 5.0 cubic feet per hour at a pressure equal to that due to a 1.5 inch water column. Inasmuch as its intensity is less than the bare mantle, it is to be preferred to the small flat fluted porcelain

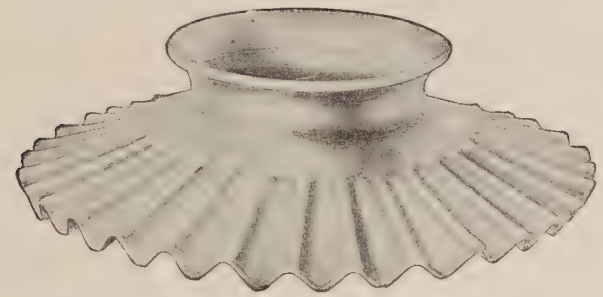


FIG. 113.—Fluted opal 8-in. reflector.

shade although its efficiency is much less. In all comparisons, both diffusion and distribution must be borne in mind, and inasmuch as it is seldom that both factors are present in one globe one must select that which is most necessary for the case in hand.

Fig. 116 shows the distribution of light about the ordinary ground glass globe shown in Fig. 117, the lamp burning 3.1 cubic feet per hour at a pressure equal to that due to a 1.7 inch water column. This globe simply diffuses and softens the light with-

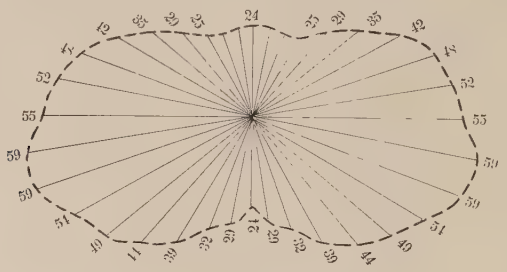


Fig. 114.—Light about a mantle burner with opal Q chimney.

out materially altering the distribution. The use of a ground glass globe or some other diffusing glass around a mantle burner is desirable in most cases because the undiffused light from the gas mantle burner is so intense as to have a blinding effect on

Fig. 115.—Opal Q chimney.

the eyes of all looking in its direction and so reducing the practical efficiency of the illumination.

Fig. 118 shows the light about a fancy globe, shown in Fig. 119, the lamp burning 3.1 cubic feet per hour at a pressure equal to that due to a 1.7 inch water column. Its absorption

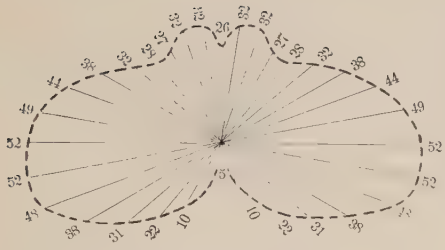


FIG. 116.—Light about a mantle burner with ground glass chimney.

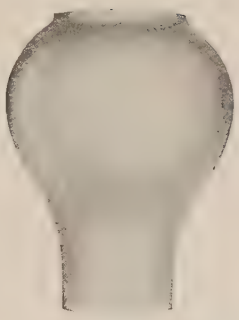


FIG. 117.—Ground glass chimney.

FIG. 118.—Light about fancy opal chimney with mantle burner.

FIG. 119.— Fancy opal chimney.

is very large. Such globes give very artistic results and good diffusion, and where economy is no object and a sufficient number can be used to get the required illumination they are to be highly recommended.

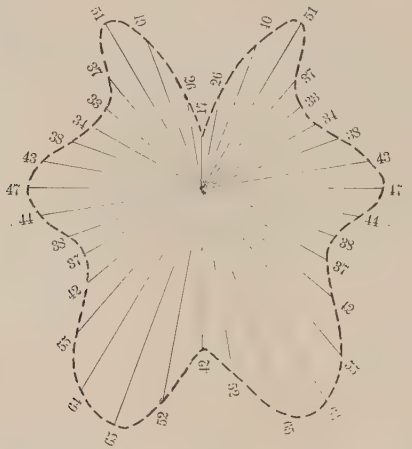


FIG. 120.—Light about a mantle burner in Class A Holophane shade.

FIG. 121.—Class A Holophane shade for mantle burner.

Fig. 120 shows the light about what is known as a Class A Holophane globe, shown in Fig. 121, the lamp burning 3.55 cubic feet per hour, at a pressure equal to that due to a 1.25 inch water column. It is designed to throw the light directly

downward but of course at the expense of the light at other angles. The diffusion obtained by such globes is almost equal to that of opal without however the large absorption, inasmuch

Fig. 122.—Light about a Class B Holophane shade with mantle burner.

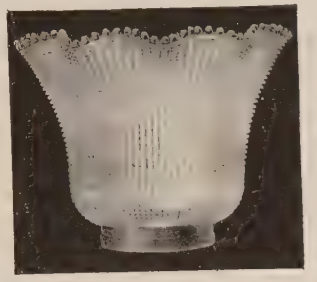


Fig. 123.—Class B Holophane shade for mantle burner.

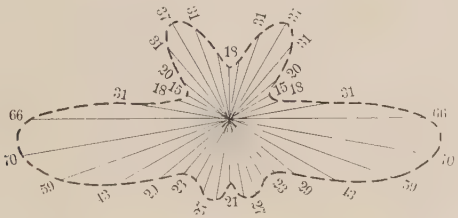


Fig. 124.—Light about a Class C Holophane shade with mantle burner.

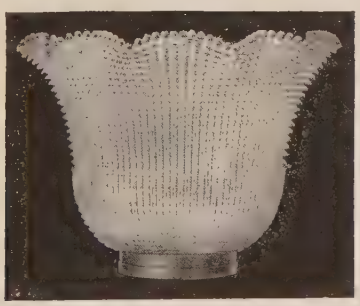


Fig. 125.—Holophane Class C shade.

as the globes are made of perfectly clear glass and depend upon their accurate design for their diffusing and redirecting qualities. Such globes owing to their prismatic faces are apt to collect the dust and should therefore be kept clean. The dust,

however, affects their appearance more than their efficiency, the additional absorption of a dusty globe in one test that was made being about 13 per cent. They should never be used in places where the air is greasy, as over stoves, as the grease is apt to settle on the prisms and is extremely difficult to remove. When such globes, however, are used intelligently they form an important adjunct to the engineer's work, as they combine both qualities of diffusion and redirecting powers with small absorption.

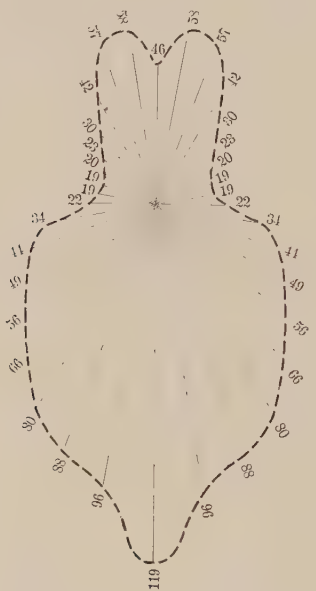


FIG. 126.—Light about a mantle burner; opal dome and opal bobesche.

Fig. 122 shows the light about a Class B Holophane globe, shown in Fig. 123, the lamp burning 3.6 cubic feet per hour at 1.5 inch pressure, designed to give a general rather than concentrated distribution.

Fig. 124 shows the light about a Class C Holophane globe, shown in Fig. 125, designed to throw the light sideways just below the horizontal in order to cover a wide area.

Fig. 126 shows the light about an opal dome and opal bobesche, or cup-shaped eye protector, shown in Fig. 127, the lamp burn-

ing 3.6 cubic feet per hour at a pressure equal to that due to a 1.6 inch water column. Such a combination is good for reading when the light is directly above the work. A bobesche should always be used with a dome shade whenever there is a possibility of the eye being able to see the mantle. As a matter of fact, bobesches should be made about half an inch deeper, as at present most of them do not come high enough to cut out all view of the bare mantle.

FIG. 127.—Opal dome and opal bobesche.

Fig. 128 shows the curve of a green dome shade and opal bobesche, burning 4.1 cubic feet per hour at 1.6 inch pressure. This makes a good reading light if directly above the work, but concentrates it too much if used on a low portable with the reader sitting alongside the table. A green dome with green bobesche is practically out of the question, owing to the large absorption of the cup. Such a combination depends entirely on the reflection from the white lining of the green dome and is very inefficient.

Fig. 129 shows the curve of a green dome and Class A Holophane bobesche, the lamp burning 3.8 cubic feet of gas per hour at a pressure equal to that due to a 1.6 inch water column. This bobesche, being higher, cuts off all view of the mantle and gives a strong light at all angles. A comparison of this with Figs. 126 and 128 is instructive and shows how easily illumination may be sometimes improved by slight changes.

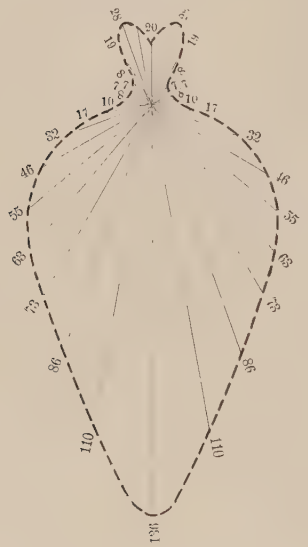


Fig. 128.—Light about a mantle burner; green dome and opal bobesche.

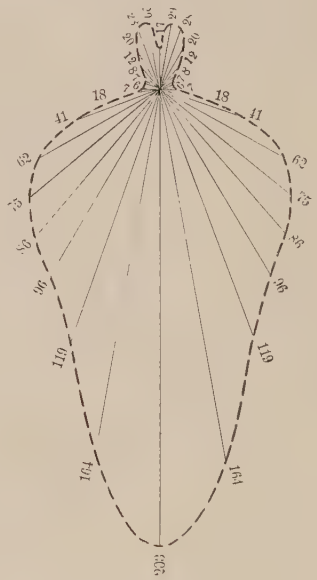


Fig. 129.—Light about a green dome and Holophane bobesche; mantle burner.

Inverted Burners.

The question of the efficiency of inverted burners compared with other types is taken up in Chapter XIV.

Fig. 130 shows the distribution in a vertical plane about an inverted burner equipped with clear air hole chimney and without an outer globe. It was operated at a pressure equal to that of a 1.5 inch water column and 3.0 cubic feet per hour consumption. It will be noted that this gives a good light at all angles below the horizontal, also that 67 per cent. of the light is below and only 33 per cent above the horizontal plane.

This should be compared with the distribution of light about an upright burner where 55 per cent. is above and only 45 per cent. below the horizontal. The mean spherical candle power is 54.

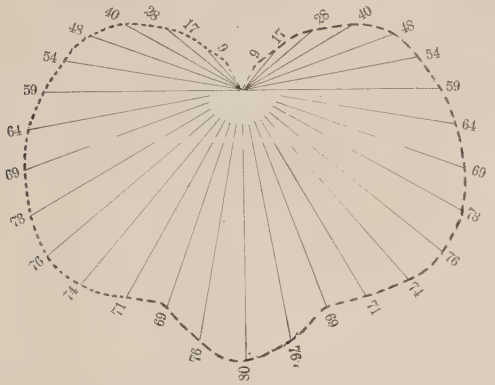


FIG. 130.—Light about a bare inverted mantle burner.

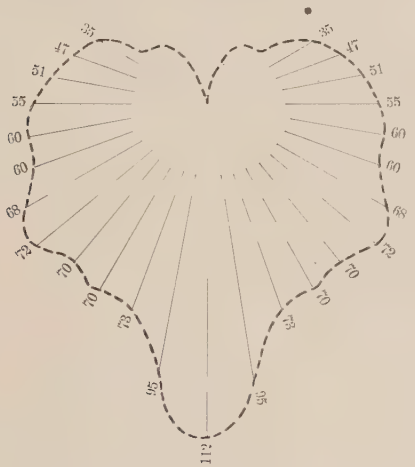


FIG. 131.—Light about an inverted burner with ground glass ball.

Owing to the high intrinsic brilliancy of the inverted mantle, which is considerably higher than the upright, such a burner should never be used without a diffusing outer or a frosted inner globe, especially as such burners generally hang lower than the upright type.

Fig. 131 shows the same burner equipped with an ordinary ground glass or sand blasted ball, operating at a pressure equal to that of a 1.5 inch water column and 3.0 cubic feet consumption. This cuts down the intensity at all angles except directly underneath where the light is increased owing to the small hole

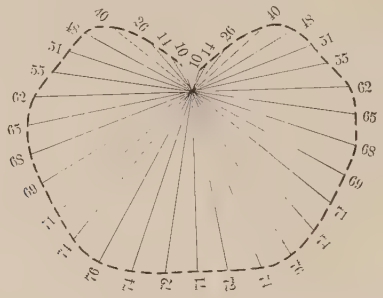


Fig. 132.—Light about an inverted burner with opal ball.

in the bottom to provide a draft. The upper part of the ground glass globe acts somewhat as a reflector thus increasing the light through the hole at the bottom.

Fig. 132 shows another burner without inner chimney but with a very dense round opal globe. The consumption of this

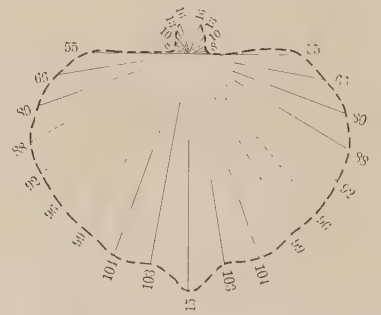


Fig. 133.—Light about an inverted burner with 9-in. flat opal reflector.

burner is not given here inasmuch as the test was purely experimental. The curve is shown in order to give an idea of the character of the distribution when using an opal globe.

Fig. 133 shows the distribution of light about the burner used in Figs. 130 and 131 equipped with a 9-inch flat porcelain

reflector and with clear inner air hole chimney. This burner took 3.1 cubic feet of gas per hour at a pressure equal to that of a 1.5 inch water column. This should be compared with Fig. 130. It shows that the light is increased at all angles under 15 degrees below the horizontal. However this combination should not be used where it is apt to come in the line of vision unless the inner chimney is frosted as the glare is altogether too intense. On the other hand, if it is desired to get a strong light down, the reflectors shown in Figs. 136 and 138 would be preferable.

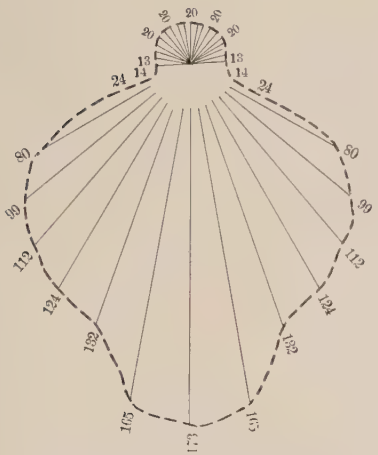


Fig. 135.—Light about inverted burner with 8-in. deep opal cone.

Fig. 134.—9-in. flat opal reflector.

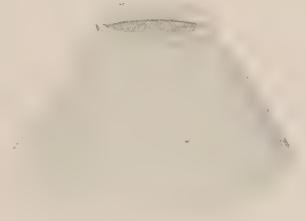


Fig. 136.—8-in. opal cone for inverted gas burner.

Fig. 135 shows the light about the same burner taking 2.8 cubic feet of gas at a pressure equal to that of a 1.5 inch water column equipped with clear inner air hole chimney and a deep eight-inch porcelain reflector shown in Fig. 136. As will be noticed, this gives a strong increase in light through a wide angle and at the same time is deep enough to shade the eyes from the bare mantle at most ordinary angles.

Fig. 137 shows the light about a prismatic reflector shown in Fig. 138, on the same burner with clear inner air-hole chimney burning 3.1 cubic feet of gas per hour at a pressure equal to that of a 1.5 inch water column. This reflector gives a very strong

light, being greater at all angles than the deep cone shown in Fig. 135. It gives an increase over the bare mantle at all angles under 25 degrees below the horizontal and is deep enough to

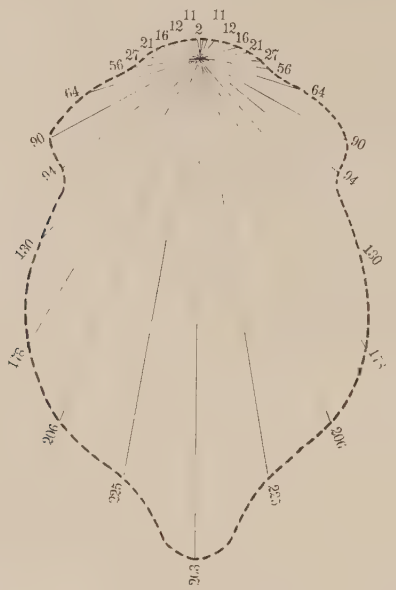


FIG. 137.—Light about inverted mantle burner with prismatic reflector.

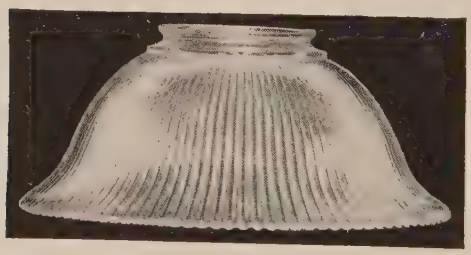


FIG. 138.—Prismatic reflector for inverted gas.

hide the mantle. It is well adapted for show windows and other places where a strong light is wanted downward.

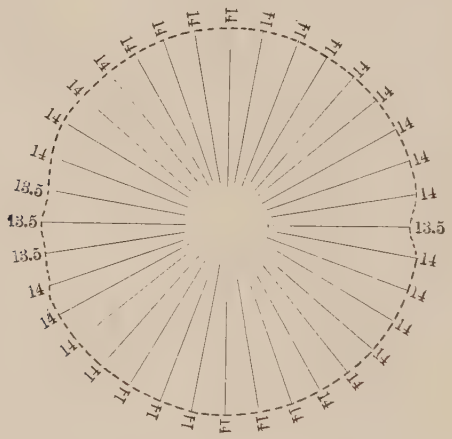
It will be seen from the representative photometric curves given here that generally speaking not only is the natural distribution

of the light from an inverted burner superior to the upright for most cases, but also the light can be more easily altered in distribution. It also lends itself better to artistic treatment than the upright type, both as regards position and glassware. On the other hand, it has its disadvantages such as tarnishing the finish of fixtures, danger from falling particles unless a globe with a bottom is provided, etc. At the present time it can be stated that the inverted burner is not yet by any means perfected but that such rapid advances are being made that we can safely count on its being an important factor owing to its appearance, efficiency and distribution.

CHAPTER VII.

ACETYLENE GAS BURNERS AND THEIR SHADES.

The flame of an acetylene burner is in general very similar to the ordinary open gas flame as regards its distribution of light. Unlike open gas, however, acetylene is extremely intense, giving from 75 to 100 candle power per square inch of flame, whereas the open gas gives in the neighborhood of five-candle power per square inch. This means that in order to use acety-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Unfortunately, in these tests the gas consumption was not measured, but was assumed to be the rated consumption of the

FIG. 140.—Light in vertical plane about open acetylene gas flame.

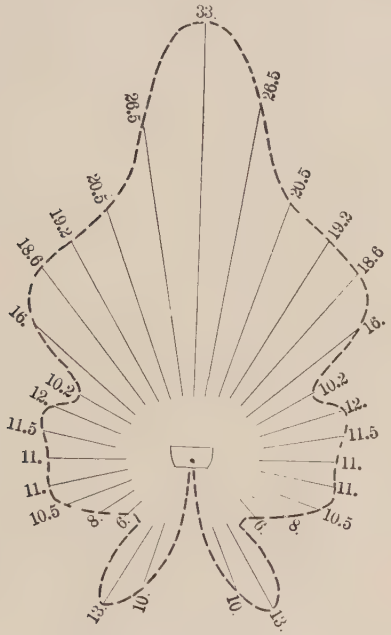


FIG. 141.—Light about acetylene gas flame in etched shade.

tip, namely, one half cubic foot of gas per hour. The tests must be considered therefore as indicative of what may be expected with different shades when used with acetylene, rather than of abso-

lute values. The tests were made with 2.5 inches of water pressure.

Fig. 139 shows the distribution of light in a horizontal plane about a bare acetylene flame. It will be noticed that the curve

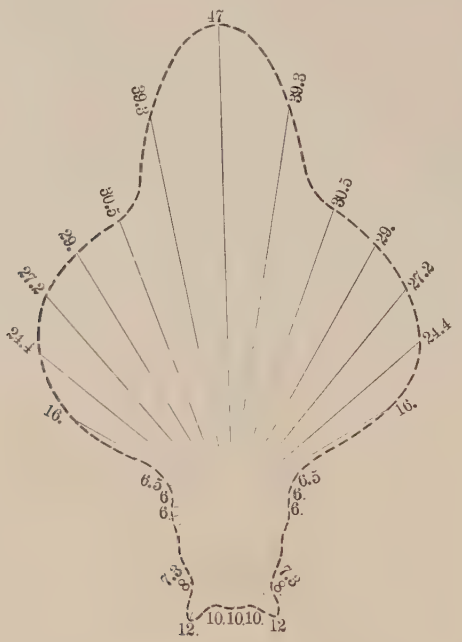


Fig. 142.—Light about acetylene gas flame in opal shade.

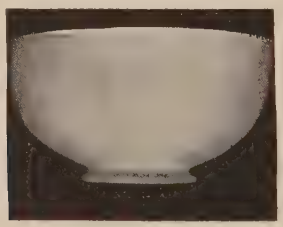


Fig. 143.—Opal acetylene shade.

is nearly circular which means that we get practically as much light whether we look at right angles or parallel to the plane of the flame. This fact (taking also into consideration that the vertical distribution, as shown in Fig. 140, is nearly uniform)

shows that the light is emanated equally in all directions and that the mean spherical candle power is practically the same as the horizontal or rated candle power. This, of course, applies to the bare flame only. Fig. 140 also shows that as much light is thrown above the horizontal as below and that unless some means be taken to direct this light downward the ceiling and high side walls must be depended upon to obtain any useful illumination from this upward light, a most inefficient process. With ordinary shades which act more or less as reflectors this condition is made still worse, and even with the Holophane type there is a large opportunity for improvement with respect to acetylene. shades.

FIG. 144.—Light about a Holophane acetylene globe.

Fig. 141 shows the distribution of light about an etched globe, shown in Fig. 108. A comparison with Fig. 107, giving the test on the same globe with ordinary gas shows about the same shape of curve. This globe gives some diffusion and is much preferable to the bare light both from the standpoint of ease on the eyes and artistic results. It gives 61 per cent of the light above and only 39 per cent. below the horizontal.

Fig. 142 shows the distribution of light about an opal globe, shown in Fig. 143. This globe gives 72 per cent. of the light above the horizontal and only 28 per cent. below, and is therefore ordinarily very wasteful. It does, however, give such fine diffusion that it greatly enhances the ability to see well and with low ceilings of a light tint is to be recommended.

Fig. 144 shows the light about a Holophane globe. This throws 43 per cent. above and 57 per cent. below the horizontal, and at the same time gives good diffusion. This shade is given as representative of this type.

At present the ordinary forms of glassware are not well suited for acetylene gas and there is a good field for the glassmakers to make shades which will be both efficient in their distribution, give good diffusion and be artistic.

CHAPTER VIII.

INCANDESCENT ELECTRIC LAMP CLUSTERS AND BOWLS.

Fig. 145 shows the mean distribution of light in a vertical plane about a cluster consisting of six 60-watt spherical frosted bulb lamps, and one 120-watt lamp of the same type, consuming a total of 480 watts. This cluster has above it a white enameled metal reflector as shown in Fig. 146. The central lamp has a white enameled prismatic reflector. As will be noticed, it gives a good general distribution of light and can be used to advantage

FIG. 145.—Light about a 480-watt incandescent cluster.

where a good light is required sideways as well as at other angles. The use of frosted lamps gives a soft mellow light, and this frosting is to be commended even at the expense of the life of the lamps.

Fig. 147 shows the distribution of light about a cluster with prismatic reflectors. This cluster contains six 16-candle power standard lamps, each lamp being in an individual prismatic reflector, and the whole being surmounted by a prismatic reflector, as shown in Fig. 148. This cluster has the advantage

of using standard lamps of any desired candle power and efficiency. In the curve given six 16-candle power, 3.1 watts per candle power lamps were used, giving a total of 300 watts. Similar clusters of this type can also be obtained for lamps of 32 to 50 candle power. This type of cluster gives a strong downward light as well as a fair amount at other angles. It should be used with frosted tip lamps, to cut off all view of the filament. It gains considerably in appearance by the use of all frosted lamps.

Fig. 149 shows the distribution of light in a vertical plane drawn through the lamps from a three-light cluster with con-

FIG. 146.—480-watt cluster.

centrating prismatic reflectors. This cluster is shown in Fig. 150. It is specially suited to lighting corridors and similar places where light is to be thrown lengthwise of the corridor. It can be used with the bottom lamp omitted if it is not desirable to have as much light immediately under the fixture as in Fig 149.

Fig. 151 shows the mean distribution of light in a vertical plane about a cluster of four 16-candle power incandescent lamps under a flat opal reflector, as shown in Fig. 152. This is a very common type of cluster, and gives a very good general distribution of light below the horizontal, but casts a shadow

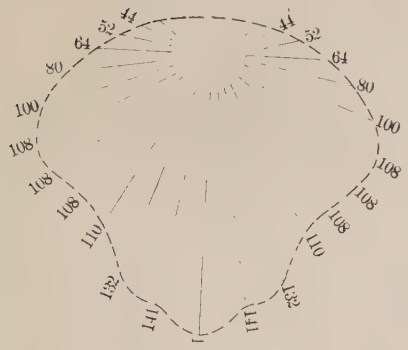


FIG. 147.—Light about a 300-watt cluster in prismatic reflectors.

Fig. 149—Light about a 3-light cluster in prismatic reflectors.

FIG. 148.—Prismatic cluster.

FIG. 150.—3-light cluster with prismatic reflectors.

on the ceiling. It should be used mainly for covering a large area. For securing light under the cluster or when placed close to high ceilings, especially in corridors, some of the other types shown are preferable. As the lamps are entirely exposed such

FIG. 151.—Light about 4-light cluster with 19 in. opal reflectors.

clusters should have frosted bulb lamps where hung low in the ordinary range of vision. Its chief objection for use in handsome stores, etc., is its entire lack of artistic appearance. It should only be used where appearance is of little value.

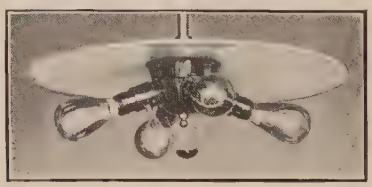


FIG. 152.—4-light cluster with opal reflector.

Fig. 153 shows the mean vertical distribution of light about a cluster of four 16-candle power incandescent lamps under a metal reflector, shown in Fig. 154. The arrangement of lamps is such that the amount escaping above and near the horizontal is much larger than is consistent with economy. It moreover

has the objections of casting a shadow on the ceiling and being inartistic in appearance.

Fig. 155 shows the mean distribution of light in a vertical plane about a cluster of four 16-candle power incandescent lamps under a prismatic glass reflector, as shown in Fig. 156.

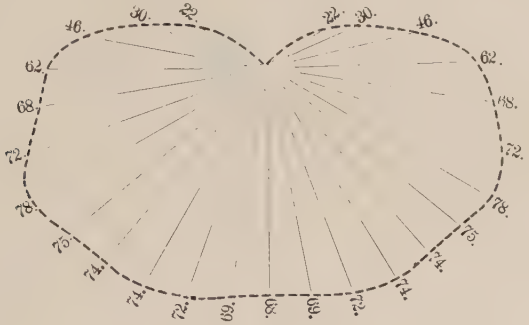


Fig. 153.—Light about 4-light cluster with 19-in. enameled metal reflector.

This reflector is used by the United States Government in its buildings where clusters are needed, one of the principal reasons why it was chosen in preference to the opal reflector being that it does not darken the ceiling as much as the opal and gives more light immediately underneath over an area 30 degrees

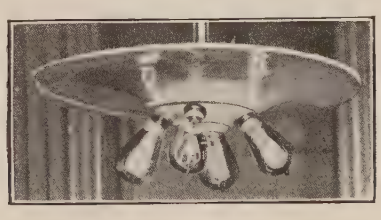


Fig. 154.—19-in. metal reflector and 4-light-cluster.

each way from the vertical. It is also somewhat better in appearance. Unless placed high and out of the line of vision it should be used with frosted lamps.

The general application of clusters is in the lighting of places which have a limited number of outlets, where it is not practicable to distribute individual lamps over the area to be lighted.

They are not to be recommended for efficiency as generally the same number of lamps distributed over the area to be lighted would give better results for a given operating cost, although costing more to install. Some types of clusters can be installed at a lower cost than chandeliers of equal appearance.

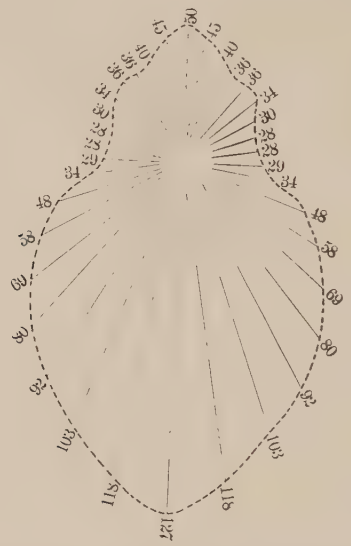


FIG. 155. Light about 4-light cluster with prismatic reflector.

FIG. 156.—4 light cluster, prismatic reflector.

BOWLS OR HEMISPHERES.

Fig. 157 gives the light distribution obtained from a sand-blasted glass bowl with a 16-candle power incandescent lamp, shown in Fig. 158. Such bowls or hemispheres are frequently used for ceiling lights and sometimes on basket fixtures. The

sand-blasted bowl evidently acts somewhat as a reflector, as much light is thrown up. In practice this upward light would, of course, be thrown against the ceiling, and most of it would probably be absorbed unless a good reflecting surface was provided inside the bowl.

Fig. 159 shows the distribution of light about a 16-candle

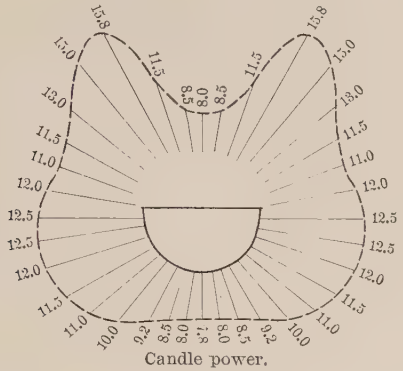


Fig. 157.—Light about a sand blasted hemisphere, 16 candle power lamp.

power incandescent lamp placed in a Holophane hemisphere designed for use on ceilings and shown in Fig. 160. This test was made without a backing of white asbestos and consequently is comparable with Fig. 157.

As hemispheres and bowls are in such common use, it becomes

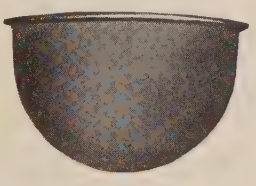


Fig. 158.—Sand blasted hemisphere.

of much importance to study the best arrangement of lights inside of such bowls. The old plan of placing clusters of lamps at indiscriminate angles inside of these bowls is usually not to be recommended. A single lamp of high candle power generally gives better results than a number of smaller units, as such a lamp can be equipped with a reflector inside the bowl.

When a cluster of lamps is used and each lamp is not equipped with its individual reflector a piece of white asbestos, being a good reflector, should be employed. This should not be placed against the ceiling but between the supporting rim and the glass, so as to bring the reflecting surface as close as possible to the

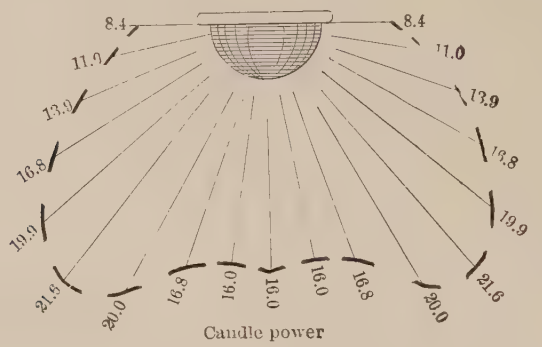


FIG. 159.—Light about a Holophane hemisphere, 16 candle power lamp.

lamps and avoid absorption by the rim, which would occur if the asbestos were placed against the ceiling. Such a reflector should be perforated with small holes which will allow ventilation but effectually prevent light escaping between the ceiling

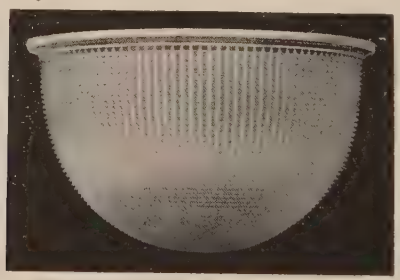


FIG. 160.—Holophane hemisphere.

and the rim, which often occurs if no reflector is used. The best arrangement, however, is to use one lamp of high candle power equipped with either a concentrating or distributing reflector, depending on the way it is desired to throw the light. While the diffusing bowl undoubtedly alters the distribution

from the lamp and reflector, nevertheless the general characteristics are preserved. It is generally desirable to use an opal or prismatic rather than an opaque reflector if the reflector comes down far enough on the lamp to cause shadows on the bowl.

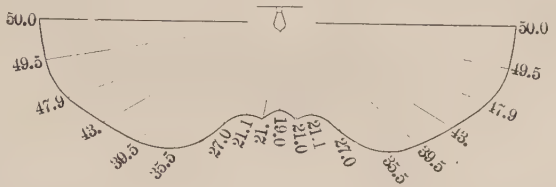


FIG. 161.—Light about 50 candle power lamp (lower hemisphere).

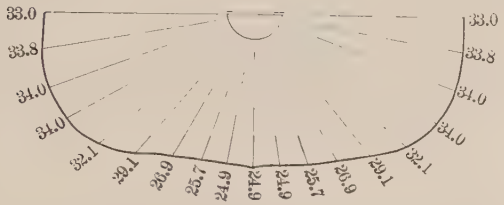


FIG. 162. —Light about ground glass bowl with 50 candle power lamp.

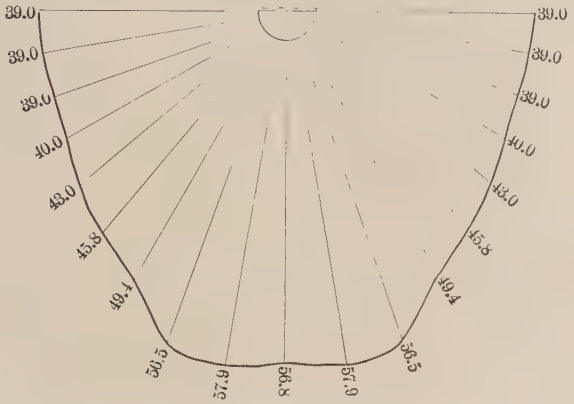


FIG. 163.—Light about ground glass bowl with 50 candle power lamp and reflector.

Fig. 161 shows the light below the horizontal from a bare 50-candle power oval anchored filament lamp which was used in the following tests on bowls. The tests without reflectors are not exactly what would occur in actual practice, inasmuch

as a certain amount of the upward light would be reflected if the ceiling were light in color. As, however, even a light ceiling quickly grows dirty, owing to the particles of dust carried upward by the warm currents of air, the tests referred to give

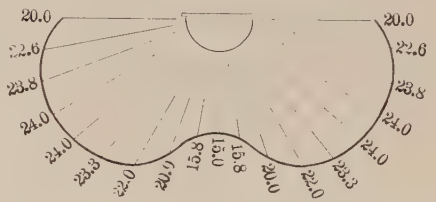


FIG. 164.—Light about a beaded bowl, 50 candle power lamp (no reflector).

a good idea of what actually happens in practice if no special attention is given to reflecting down the upward light.

Fig. 162 shows the light distribution from a 50-candle power incandescent lamp in a 12-inch ground glass bowl, no reflector being provided on the lamp. The great increase in useful

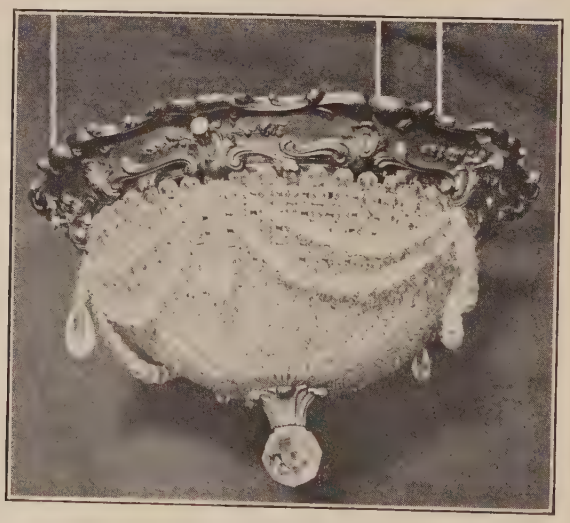


FIG. 165.—Beaded bowl.

illumination by the use of a reflector over the lamp in the bowl is shown in Fig. 163.

Fig. 164 shows the light distribution from a 50-candle power lamp in a 12-inch glass bowl covered with strings of glass beads,

shown in Fig. 165. Such a bowl absorbs a great amount of light, since the beads act as prisms to turn the light in various directions, where it is lost by multiple reflection and refraction. Where cut glass beads are used around lamps in this manner,

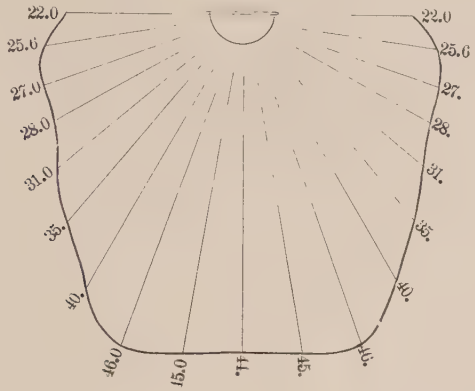


FIG. 166.—Light about a beaded bowl with 50 candle power lamp and reflector.

due allowance must be made (in this case about 50 per cent.) for their high absorption by providing much larger candle power in lamps than would otherwise be necessary.

The illumination from this beaded bowl, however, can be very much increased by the use of a prismatic reflector over

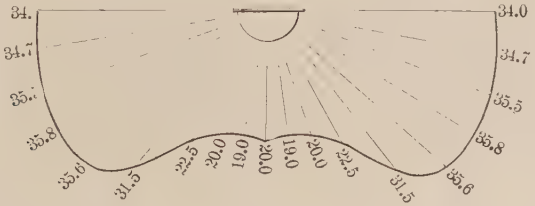


FIG. 167.—Light about an opaline bowl with 50 candle power lamp (no reflector).

the lamp, as is shown in Fig. 166, which gives the light distribution about the same beaded bowl with a reflector over the lamp. The increase in the total amount of light below the horizontal is 34 per cent. and in the zone 60 degrees each side of the vertical,

which in hemisphere lighting is generally the most important, no less than 60 per cent.

Fig. 167 shows the light about a 50-candle power lamp in an opaline 12-inch bowl, while Fig. 168 shows the light distri-

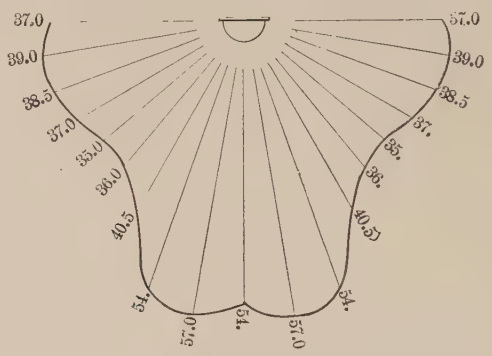


FIG. 168.—Light about an opaline bowl with 50 candle power lamp and reflector.

bution when using a reflector over the lamp in the same opaline bowl.

Fig. 169 shows the light distribution from a 50-candle power lamp in a 12.5-inch Holophane bowl. While the downward

FIG. 169.—Light about Holophane bowl with 50 candle power lamp (no reflector).

distribution of light in this case is considerably greater than with any of the other bowls without reflectors on the lamps and is almost as great as when reflectors are used on the other bowls, the amount of downward light with the Holophane bowl can

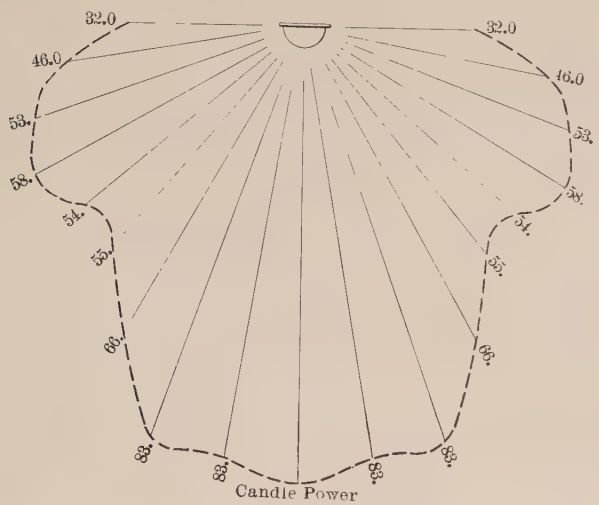


FIG. 170.—Light about Holophane bowl with 50 candle power lamp and reflector.

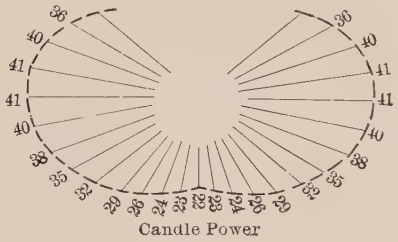


FIG. 171.—Light about a 13-in. sand blasted ball with three lamps (no reflectors).

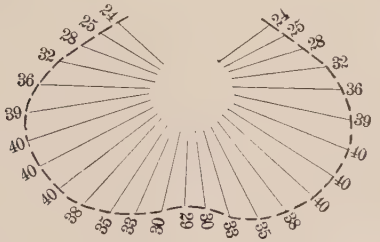


FIG. 172.—Light about 13-in. sand blasted ball with 3 lamps and reflectors.

be greatly increased by the use of a reflector over the lamp, as is shown by the light distribution in Fig. 170.

It is sometimes possible when hemispheres, large balls and spheres already installed are placed high with a number of lamps in them, to put small reflectors on the lamps and so increase the downward light materially. This is not as good as having one large lamp and reflector, but it is to be considered as a method of making the best of a bad arrangement.

Fig. 171 shows the mean distribution of light in a vertical plane around a ground glass ball 13 inches in diameter with three 16-candle power lamps hung vertically in it without reflectors. The effects of adding small prismatic reflectors (3.5 inches in diameter) over these lamps is shown in Fig. 172. It is probably possible to design smaller reflectors specially built for this class of work, which would give better results.

CHAPTER IX.

NERNST LAMPS AND THEIR GLOBES.

Fig. 173 shows the mean distribution of light in a vertical plane about a three-glower, 220-volt, 264-watt Nernst lamp fitted with a clear six-inch glass ball globe. The mean spherical candle power is 81.

Fig. 174 shows the mean distribution of light in a vertical plane about a three-glower Nernst lamp with a six-inch sand-blasted or roughed globe.

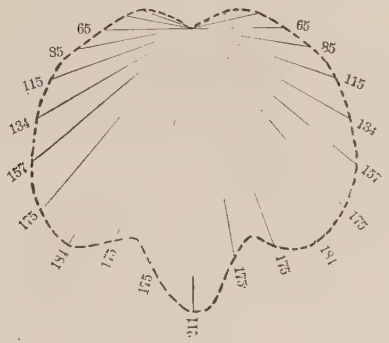


Fig. 173.—Light about 3 glower Nernst lamp, clear globe.

Fig. 175 shows the mean distribution of light in a vertical plane about a three-glower Nernst lamp with a glass ball globe having a slightly bluish tinge.

Fig. 176 shows the mean distribution of light in a vertical plane about a three-glower Nernst lamp with an opalescent ball globe.

The natural distribution of light from the Nernst lamp is very similar to that of an incandescent lamp with certain reflectors, the greater portion of the light being thrown down so that for the best results it should be hung over the area to

be lighted and it should not be expected to light too large an area.

Fig. 177 shows the light about a three-glower Nernst lamp with a Holophane distributing class B globe and indicates how

Fig. 174.—Light about 3 glower Nernst lamp, sand blasted globe.

the Nernst lamp can be made to give a wider distribution of light.

Fig. 178 shows the light in a horizontal plane 30 degrees below the horizontal with the same sand-blasted globe and lamp as shown in Fig. 174. This shows the candle power is not

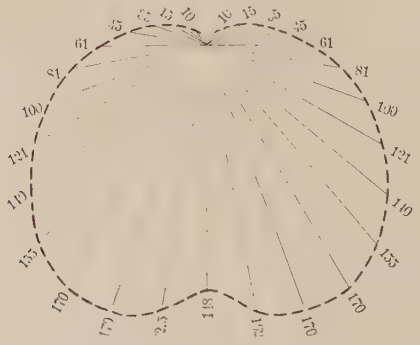


Fig. 175.—Light about 3 glower Nernst lamp, bluish tinged globe.

uniform in all directions. The effect of the sand-blasted globe is to make it more uniform than with a clear globe. With the Holophane globe it is even more uniform than with the sand-blasted globe.

The distribution of light about the one, four and six-glower lamps is very similar to that about the three-glower lamp, for which tests have been shown. The efficiency increases with an increase in the number of glowers. Taking the amount of useful downward light (mean lower hemispherical candle power) per glower as 100 per cent. for the three-glower lamp, the amount of light per glower with the various sizes of lamps is about as follows:

1 Glower	.....	87 per cent.
3 "	.....	100 per cent.
4 "	.....	113 per cent.
6 "	.....	119 per cent.

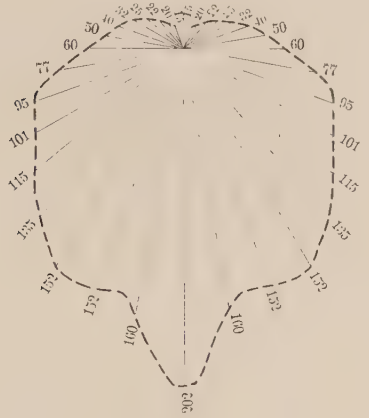


FIG. 176.—Light about 3 glower Nernst lamp, opalascent globe.

Although the Nernst lamp naturally gives most of its light downward a large increase in light at all angles below 20 degrees from the horizontal can be secured by the use of opal, prismatic glass or metal reflectors, an enameled metal reflector giving as much as 70 per cent. increase directly down.

The Nernst lamp is well suited to the lighting of stores, halls and churches, where it can be placed high above the area to be lighted. It is important to place it high, out of the line of ordinary vision, because a unit of such high candle power hung low has a blinding effect on the eye. Because of the downward distribution of the light as seen from the various tests given, the hanging of Nernst lamps low is likely to result in too much

light immediately under each lamp and insufficient light midway between the lamps.

Because of the intense brightness of the light from the glowers it is never advisable to use these lamps with globes of clear or very lightly tinged opalescent glass, except where the lamps are

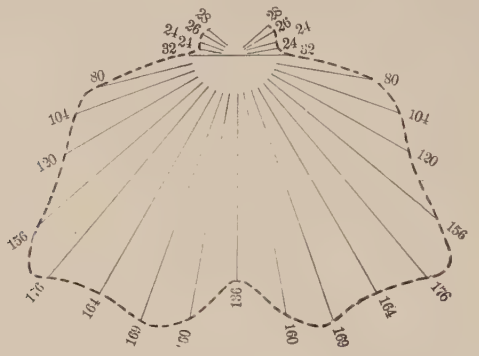


FIG. 177.—Light about 3 glower Nernst lamp, Holophane Class B globe.

placed so high that they are practically never seen or are hung above sky lights which act as diffusers. Sand-blasted ball globes are much to be preferred to the globes with slight bluish tinge which are so frequently used with these lamps. The diffusion is excellent with the sand blasted globe, so that the whole globe ap-

FIG. 178.—Light about 3 glower Nernst lamp, Horizontal plane, 30^0.

pears to be aglow, whereas with the blue tinged ball the intensely bright glowers can be seen, which is not only bad because of the blinding effect on the eye, but also because of its inartistic appearance. Where the lamp is used for lighting streets and corridors it must be remembered that the horizontal distribution

about the light is not uniform and that the lamp should be hung so as to throw the maximum light lengthwise of the corridor. The lamp produces excellent artistic results when the complete unit is placed inside of large ground glass or Holophane spheres.

The Nernst lamp is frequently used in locations where otherwise an arc lamp would be used. Its steadiness is a strong point in its favor when compared with arc lamps. It also gives naturally more useful light below the horizontal than an alternating current arc lamp taking the same amount of energy. As the Nernst lamp is made for alternating current only it is to be considered only where such a current supply is available.

CHAPTER X.

ELECTRIC ARC LAMPS.

The measurement of the light about arc lamps with a photometer is a matter of considerable difficulty. The light at any one point varies considerably owing to the wandering of the arc from one point to another on the carbon tips and variations in the length of arc. Other things causing variation in results are the size and quality of carbons used and the glassware. The results obtained by different observers at different times are apt to vary considerably. It is always necessary to take the aver-

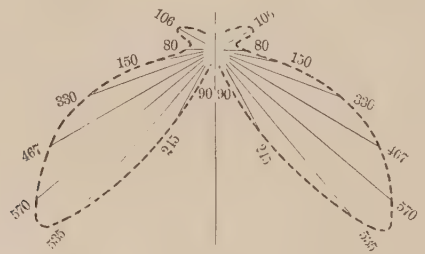


FIG. 179.—Light about 5 ampere d. c., 110 volt arc, clear inner globe alone.

age of a large number of observations to secure approximately correct average results. The photometry of electric arc lamps is in fact almost as troublesome as that of gas lamps, as mentioned at the beginning of Chapter VI. These things should always be remembered when controversies over the candle power of arc lamps arise.

Fig. 179 shows the distribution of light about an enclosed arc lamp operated from a constant potential 120-volt circuit with about 82 volts at the arc and a current of about five amperes, the total power consumption being about 600 watts. The arc was equipped with a clear glass inner globe alone without any other glassware. The maximum candle power is given at about

45 degrees below the horizontal, after which the light falls off rapidly. The use of nothing but a clear glass inner globe is almost never permissible in interior lighting, because of the great brilliancy of the arc and the dazzling effect which its undiffused light would have on the eye. The mean spherical candle power in this test was 213.

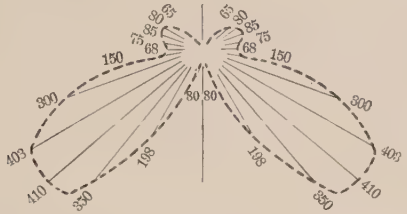


FIG. 180.—Light about 5 ampere d. c. 110 volt arc, clear inner and outer globes.

The distribution and amount of light is affected considerably by simply adding a clear glass outer globe over the clear glass inner globe, the result of which is shown in Fig. 180. Practically nothing in distribution is gained by this procedure and the glare is nearly as bad as before.

Fig. 181 shows the same lamp with an opal inner globe alone. The effect of the opal inner globe is to cause more light to be

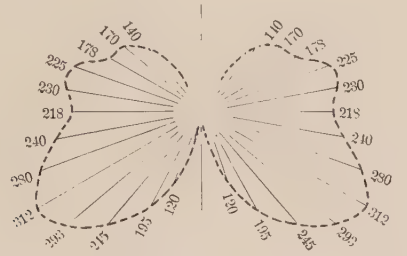


FIG. 181.—Light about 5 ampere d. c. 110 volt arc, opal inner globe alone.

thrown above the horizontal, which in itself is not usually a desirable thing to accomplish in interior lighting. The opal inner globe, however, diffuses the light so much better than the clear glass that the illuminating effect is much better, since the light is not so blinding to persons in the room and they can therefore see objects in the room better as explained before.

This is an arrangement in common use. With the aid of a reflector it becomes very efficient. The small inner globe, however, does not offer as much diffusing surface as could be desired and the arc should therefore not be placed in the line of vision.

Fig. 182 shows the effect of adding a clear outer globe over

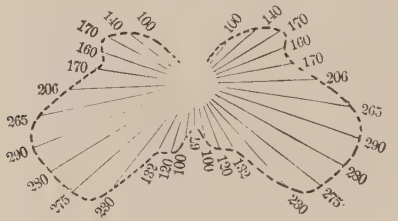


FIG. 182.—Light about 5 ampere d. c., 110 volt arc, opal inner and clear outer globe

an opal inner globe, this being to further cut down slightly the light and to somewhat change the distribution. The clear outer globe does away with the shadow or dark area immediately under the lamp, which appears when the opal inner globe is used. However, a clear inner and opal outer globe (see Fig.

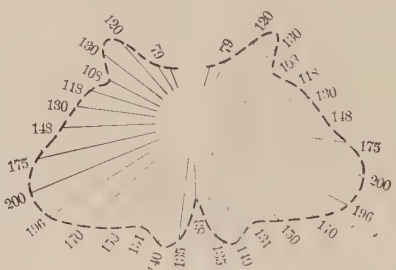


FIG. 183.—Light about 5 ampere d. c., 110 volt arc opal inner and outer globe.

184) gives far better diffusion and about the same loss in the glass, and is much to be preferred.

Fig. 183 shows the light from the same lamp enclosed in both an opal inner and an opal outer globe. The diffusion in this case is excellent, but of course the light is materially reduced. There is also considerable strengthening of the light directly

below the arc which is sometimes of a good deal of value. Further, the violet rays are largely filtered out, producing a white light of better quality. The inequality of light due to the wandering of the arc is considerably reduced by the opal globes. All told, for general interior work this is probably the best combination.

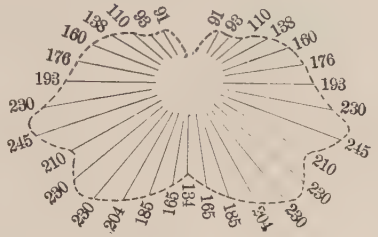


FIG. 184.—Light about 5 ampere d. c., 110 volt arc, clear inner and opal outer globe.

Fig. 184 shows the same direct current lamp with a clear inner and opal outer globe. As far as diffusion is concerned, this is probably the second best combination for interior lighting, as the size of the opal outer globe causes better diffusion than the small opal inner globe. It does not lend itself well to the use of a reflector, so that some efficiency is usually sacrificed as

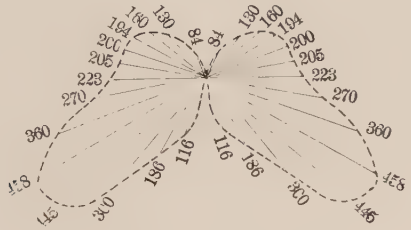


FIG. 185.—Light about 5 ampere d. c., 110 volt arc, opalescent inner globe and $\frac{1}{2}$-in. carbons.

compared to the use of an opal inner globe alone. With the latter reflectors can be used to increase the downward light, but in such case the lamp must be hung high out of the range of vision.

Fig. 185 shows the result of a test also made by the Electrical Testing Laboratories and presented in a paper by Mr. George

N. Eastman before the American Institute of Electrical Engineers at Chicago on March 28, 1905. This test is on a five-ampere direct current constant potential arc lamp operated with 80 volts at the arc, an opalescent inner globe being used; the lamp was provided with the usual 0.5-inch carbons. With

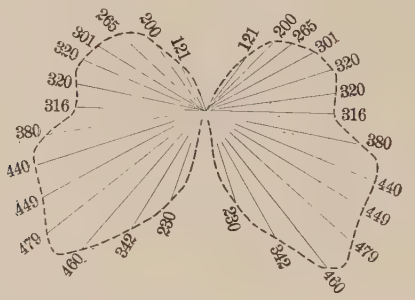


FIG. 186.—Light about 5 ampere d. c., 110 volt arc, opalescent inner globe and $\frac{5}{16}$ in. carbons.

the same current and voltage and the same inner globe, but with 5/16-inch carbons, the distribution of light shown in Fig. 186 was obtained, the total increase in mean spherical candle power in Fig. 186 with small carbons over Fig. 185 with large carbons being 38.2 per cent. The gain in efficiency by the use of small

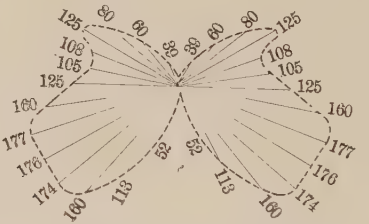


FIG. 187.—Light about $3\frac{1}{2}$ ampere d. c., 110 volt arc, opalescent inner globe and $\frac{1}{2}$ in. carbons.

carbons is even more marked with arcs of smaller current. In this connection it should be remembered that arcs employing a small current are not as efficient as those using a larger current.

Fig. 187 shows the light about a 3.5-ampere arc lamp with $\frac{1}{2}$-inch carbons, while Fig. 127 shows the light from the same 3.5-ampere arc lamp equipped with 5/16-inch carbon, the total

increase in light in this case being 52.8 per cent, due to the use of the smaller carbons. Besides the great increase in efficiency by the use of smaller carbons the light is much steadier because the arc does not have the same opportunity to wander. This in itself is an advantage, as one of the greatest objections to the

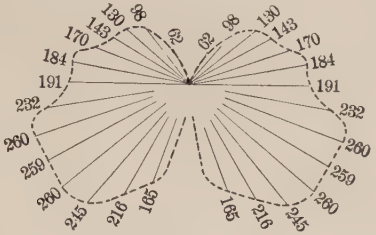


FIG. 188.—Light about 3½ ampere d. c., 110 volt arc, opalescent inner globe and $\frac{5}{16}$ in. carbons.

ordinary arc lamp with large carbons is its unsteadiness. The small carbon arc also has less preponderance of violet in the color of its light. In other words, it approaches nearer to daylight than the large carbon lamp. While the small carbon lamps require somewhat more frequent trimming than large

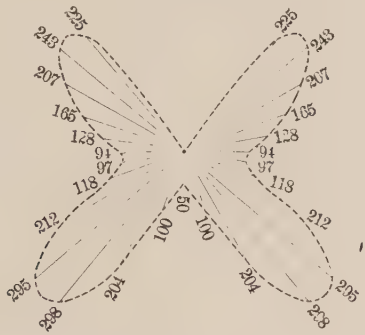


FIG. 189.—Light about 5.7 ampere a. c., 110 volt enclosed arc clear inner globe.

carbon lamps, this is compensated for by the increase in efficiency. The small carbon arc maintains its efficiency better between trimmings because there is not such a blackening of the inner globe as with large carbons. The cost of carbons and trimming labor is, of course, higher the smaller the carbons.

Fig. 189 shows the distribution of light about an en-

closed alternating current arc lamp operated from a 118-volt constant potential circuit of 60-cycle frequency. It was adjusted so as to take about 5.7 amperes with 77 volts at the arc. The power factor under these conditions was approximately 87 per cent. for the arc and 62 per cent. for the lamp. The power consumption was, therefore, about 416 watts. In Fig. 189 the arc was equipped with a clear glass inner globe and had the usual small white enameled reflector immediately at the top of the enclosing globe, as used on G. I. arc lamps. This reflector is 4.5 inches in diameter and is so placed that it intercepts all rays of light above 58 degrees above the horizontal. As the light-giving crater forms on the ends of both upper and lower carbons on the alternating current arc lamp, a large amount of light is thrown above the horizontal in spite of the small

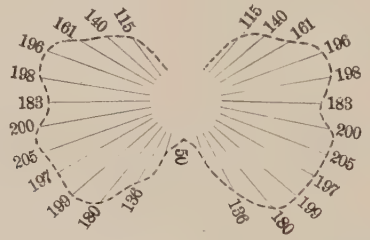


FIG. 190.—Light about 5.7 ampere a. c., 110 volt enclosed arc opal inner globe alone.

reflector which is used. The mean spherical candle power is 152.

Fig. 190 shows the effect of substituting an opal inner globe, which gives the conditions usually found in interior lighting except that usually a large opal reflector is used in addition to reflect down some of the rays thrown above the horizontal, where they are of little use.

The equipment of an alternating current arc lamp with a proper large reflector adds greatly to the useful downward light. Thus a shallow opal dome-shaped reflector, 16 inches in diameter by four inches deep, will increase the amount of light below the horizontal 50 per cent., according to the tests made for the National Electric Light Association by Prof. C. P. Matthews and reported in 1900. Without proper reflectors an alternating current arc is likely to be a very inefficient means of securing interior illumination. With such reflectors the alternating arc

can be made to approach the direct current arc in practical illuminating efficiency.

The Flaming Arc.

The flaming arc lamp is coming into use in America for outdoor street lighting and advertising purposes, and is used considerably for outdoor work abroad. The efficiency of the arc itself in some of the types is as much as five times that of the five-ampere enclosed direct current arc, using 0.5-inch carbons. At present writing it is not to be considered for interior lighting except in such places as foundries, factories, and large exhibition buildings where the fumes given off from the flaming carbons are not objectionable, and where it can be hung high. For such places it should give good results.

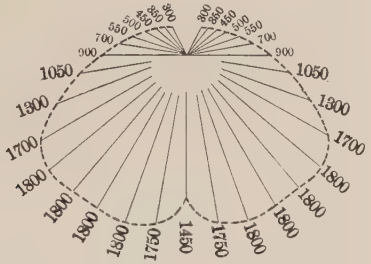


Fig. 191.—Light about 8 ampere flaming arc.

Fig. 191 shows the light about one type of eight-ampere flaming arc equipped with a clear globe and requiring 45 volts at the arc. The mean spherical candle power is 1020. The distribution is mainly downward, so it is important to hang these lamps high, both to secure proper diffusion and avoid such a powerful source of light in the ordinary range of vision. The light is so great in volume and intensity that large diffusing globes should always be used. The color of the light depends on the chemicals which are used in the carbons. The highest efficiency is obtained with carbons giving a reddish yellow light. A white light can be obtained with a sacrifice of from 25 to 50 per cent. in efficiency. Care should be taken not to place such arcs near electric signs, as such powerful illuminants will spoil the effect of any less intense lights placed in their vicinity.

CHAPTER XI.

GAS ARC LAMPS.

Before taking up the study and performance of gas arc lamps the reader is referred to the introductory remarks of Chapter VI relative to the various factors which enter into gas testing. The question as to the relative efficiency and value of individual burners and gas arcs is considered in the Chapter on Comparison of Illuminants. Two gas arc lamps of well known makers were selected for test as being representative of gas arc lamps in general.

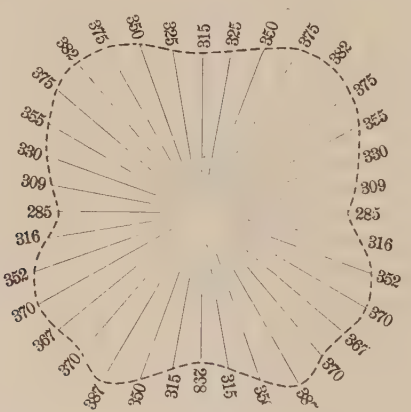


FIG. 192.—4-light gas arc horizontal distribution, clear globe.

Fig. 192 shows the distribution of light in a horizontal plane about the gas arc lamp shown in Fig. 194, equipped with clear glass globe and flat porcelain reflector. It will be noted that the distribution is unsymmetrical, the maximum exceeding the minimum by 35 per cent. This is due to the shading of the mantles. In one position only two mantles are visible, while by shifting the point of view 30 degrees three of the mantels are entirely visible and the fourth partly so.

It should, therefore, be noted that when installing such lamps they should be placed so as to secure their maximum candle power in the proper direction, as it is thus possible to materially

FIG. 193.—Light about a 4-light gas arc, clear globe, flat porcelain reflector.

increase the illumination in given directions without any additional cost. This is a point of considerable practical use, but seldom taken advantage of.

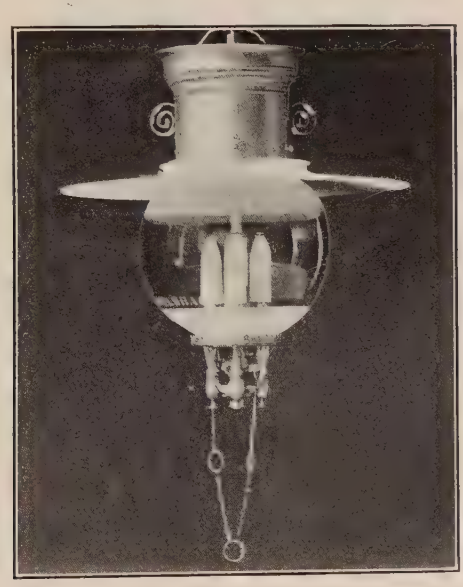


FIG. 194.—Four-light gas arc, clear globe, flat porcelain reflector.

While no horizontal distribution tests were made with alabaster globes, as the lamps so tested was equipped with clear globe and flat porcelain reflector, results of tests on electric lamps giving unsymmetrical horizontal distribution show clearly

that a dense diffusing globe like alabaster tends to greatly offset this lack of uniformity.

Fig. 193 shows the distribution of light in a vertical plane about the same lamp, as shown in Fig. 194.

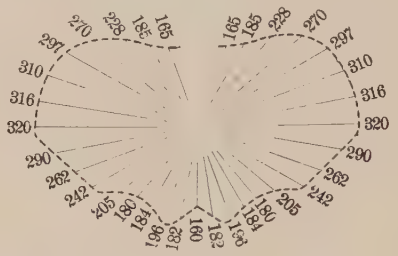


Fig. 195.—Light about a 4-light gas arc alabaster globe no reflector.

Fig. 196. Four-light gas arc, alabaster globe, no reflector.

Tests were made in two vertical planes, the first, normal to the common vertical plane of two adjacent mantles. In this case only two mantles were visible. The second vertical plane investigated was 45 degrees removed from the first. In this plane three mantles were visible. The indicated mean spherical

candle power and the indicated lower mean hemispherical candle power values were computed from the intensities determined by measurements in these vertical planes. As the distribution of light in the horizontal plane about the lamp is non-uniform

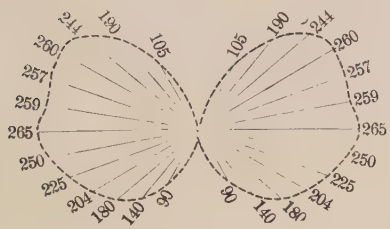


FIG. 197.—Light about a four-light gas arc, clear globe, no reflector.

FIG. 198.—Four-light gas arc clear globe no reflector.

FIG. 200.—Four-light gas arc, alabaster globe, no reflector.

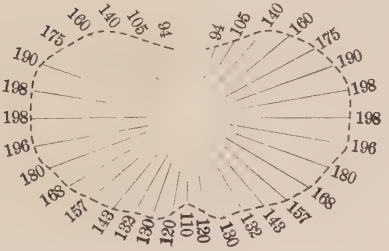


FIG. 199.—Light about a four-light gas arc, alabaster globe, no reflector.

neither of the values given represents the true mean spherical candle power, which will lie somewhere between them. This can be verified at once by reference to the horizontal distribution curve, shown in Fig. 192.

Fig. 195 shows the distribution in the second vertical plane about the same lamp equipped with alabaster globe and without reflector, as shown in Fig. 196. It will be noted that, except directly underneath, there is a material increase in the light due to the use of the clear globe, but on account of the diffusion obtained by the alabaster globe, it is generally speaking, better to sacrifice the increase of light, whenever the mantles are likely to fall directly in the line of vision. The results of the test on this arc are as follows:

	Clear Globe First Plane.	With Opal Reflector Second Plane.	Alabaster Globe Second Plane.
Pressure in inches of water	1.5	1.5	1.5
Consumption in cubic feet of gas per hour	21.0	21.0	22.5
Indicated mean spherical candle power	230.	267.	245.
Indicated mean lower hemispherical candle power	281.	345.	240.
Mean spherical candle power per cubic foot	11.	12.7	10.9
Mean lower hemispherical candle power per cubic foot of gas per hour	13.4	16.4	10.7

Fig. 197 shows the distribution in the second vertical plane of a gas arc lamp, shown in Fig. 198, equipped with clear glass globe and without reflector. With this arc tests were made in three vertical planes, the third being half way between the first two mentioned in the case of the previous test. In the third plane, it is possible to see part of the fourth mantle.

The results of the tests on this arc are as follows:

	Clear Globe without Reflector.		Alabaster Globe.
	First Plane.	Second Plane.	Third Plane.
Pressure in inches of water	1.6	1.6	1.6
Consumption in cubic feet of gas per hour	18.0	18.0	19.0
Indicated mean spherical candle power	177.	200.	162.
Indicated mean lower hemispherical candle power	168.	185.	166.
Mean spherical candle power per cubic foot	9.8	11.1	8.5
Mean lower hemispherical candle power per cubic foot of gas per hour	9.3	10.3	8.7

The remarks with reference to the mean spherical candle power values of the first gas arc lamp apply also to this test.

Fig. 199 shows the distribution in the third vertical plane about the same lamp equipped with alabaster globe but no reflector, as shown in Fig. 200.

Relative to this arc lamp it should be noted that it was not provided with adjustments which permitted it to be operated on the low pressure as satisfactorily as the first one mentioned. Both lamps, however, were operated on the pressure which obtains in New York City.

CHAPTER XII.

VAPOR LAMPS.

The mercury vapor arc lamp is the principal vapor electric lamp in commercial use. The light is bluish green in color and since it gives off no red rays its use is out of the question where it is desirable to see objects in their ordinary colors as we know them. There are a large number of places, however, where color is of no importance and where the mercury vapor lamp gives excellent results, as, for example, in factories, draughting rooms, warehouses and work rooms of all kinds where color values are not needed and where the important thing is a good

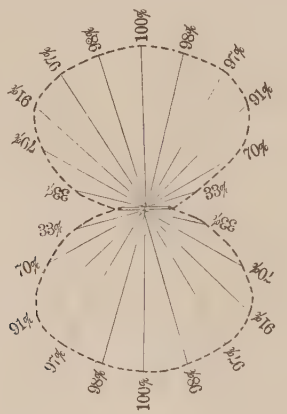


FIG. 201.—Light about mercury vapor lamp without reflector.

diffused light to work by. The two points strongly in its favor are its high efficiency and its excellent diffusion of light. As to efficiency it is undoubtedly next after the flaming arc lamp, the most efficient electric illuminant in commercial use at the present writing. On account of the color of the mercury vapor lamp, the length of the tube and other unusual factors the photometric testing of these lamps offers grave difficulties and no accurate absolute figures are available at present writing. It is safe to say that these lamps will not require more than about one watt per mean spherical candle power when operated at an

efficient point. The general form of the distribution of light in a vertical plane about a horizontal mercury vapor tube without any reflector over the lamp is shown in Fig. 201. Absolute candle power values are not given for reasons before stated. The effect of putting a white enameled reflector over the tube is shown in Fig. 202, where the values are given in percentages of the maximum value obtained without reflector. The reflector increases the light immediately below the lamp 213 per cent. and also increases it at all other angles up to 20 degrees below the horizontal. For most positions the reflector is advisable.

Besides being very efficient the fact that the light comes from a long tube gives excellent diffusion, so that the light is almost as free from sharp shadows as daylight. This makes it a good light to work by. Besides being free from shadows the light is similar to daylight, in that there is not as much

FIG. 202.—Light about mercury vapor lamp with reflector.

glare and glisten from paper, tools and machine work as with most artificial light sources which are smaller and more intense. This fact even more than the absence of sharp shadows is the cause of its being comfortable to work under. These lamps are made only in large sizes, one taking 385 and another 193 watts. For this reason the general practice when using them is to produce enough general illumination all over the room to be lighted so that close work can be done anywhere in the room rather than to concentrate light at special points for special purposes, as with smaller and less efficient illuminants.

The Moore vacuum tube light is hardly to be considered a commercial proposition at present writing, and as reliable data on it is not yet available the subject is not taken up.

CHAPTER XIII.

DEMONSTRATION ROOM TESTS.

In Chapter V are given a large number of tests on reflectors, shades and globes for individual incandescent electric lamps. These tests show the amount of light given out in various directions from an incandescent lamp as equipped with various glassware. Although these tests as given tell the experienced eye just what may be expected from reflectors and globes in practice, it is, nevertheless, instructive to be able to note the practical effect of different reflectors, shades and globes in the lighting of a room. For this reason there are reproduced here a number of photographic demonstration room tests. To make these tests, two small rooms were constructed side by side. The dimensions of each room were about one-third those of a room 13 feet square by 9 feet high, thus giving conditions comparable to the average small residence or office room. The side of the room toward the observer was left open so that the lighting effects on the floor, walls and ceiling could be noted. The same color was used on the floors, walls and ceilings of the two rooms. The ceilings were gray and the walls light green. By equipping the lamp in the right hand room with one kind of reflector shade, or globe and the lamp in the left-hand room with another kind, the comparative practical results in the lighting of the room can be seen; the source of light being shaded from the eye by a piece of black cardboard which prevents the direct rays from shining into the eye or the camera and interfering with a careful comparison. By using the same kind of incandescent lamps in both rooms the light is practically the same color in both, and hence will have the same value on the photographic plate. The two rooms can therefore be photographed as a pair, as seen in the tests which follow, and a record of the tests can thus be preserved. This method of testing is not to be considered as accurate as testing with a photometer and the

results given are purely comparative. Nevertheless it has the advantage that it shows the practical effect of using different reflectors, shades and globes in the average room. It also takes into account the effect of reflection from the walls of a room which photometric tests do not. In all of the following tests, unless otherwise specified, one 16-candle power incandescent lamp was used in each room. The total amount of light and electrical energy in each room being the same the differences shown are, therefore, due entirely to the different effects of the reflectors, shades and globes used.

In test No. 1, which is here shown, the left-hand room has a bare 16-candle power incandescent lamp, hanging at the usual height of a lamp on a pendant. In the right-hand room is a lamp at the same height equipped with the fluted opal cone reflector shown in Fig. 20. This reflector adds considerably to the light thrown down toward the floor, this light being secured at the expense of the high side walls and ceiling, which are considerably darker than where the bare lamp with no reflector is used.

In test No. 2 the left-hand room has a bare lamp on a pendant. In the right is a lamp equipped with the prismatic reflector shown in Fig. 34. This reflector concentrates considerable light immediately under the lamp without materially darkening the ceilings and side walls.

Test No. 3 has in the left room a lamp in a very concentrating form of prismatic reflector, shown in Fig. 36. In the right is a bare lamp. A great amount of light is concentrated under the lamp in the left-hand room. This represents an extreme case of changing the distribution of light about the bare lamp and concentrating it at one point with the aid of a reflector.

Test No. 4 has in the left room a lamp in the corrugated mirror desk shade, shown in Fig. 54, as against a bare lamp in the right-hand room. This is also an extreme case of directing the light downward at the expense of the walls and ceilings. In this case the upper walls and ceilings in the left-hand room are lighted entirely by reflection from the intensely lighted floor and lower side walls.

Test No. 5 has in the left room a ground glass hemisphere at the ceiling, shown in Fig. 158, and at the right a Holophane hemisphere at the ceiling, shown in Fig. 160. The amount of

light thrown on the floor in the latter case being notably greater.

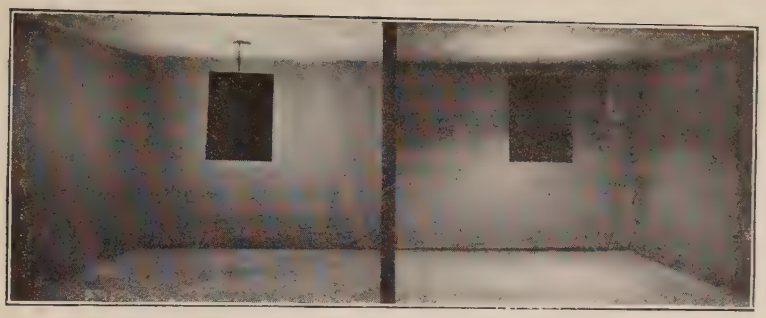
Test No. 6 has in the left room a Holophane Class A globe, designed to throw the light downward on a pendant, shown in Fig. 79, and at the right a prismatic reflector, at the ceiling, shown in Fig. 34. The floor is considerably better lighted with the prismatic reflector at the ceiling than with the Class A Holophane diffusing globe on the pendant. The idea in making this test was that when lamps are placed on pendants or on chandeliers they should be equipped with diffusing globes to avoid the glare of the lamps in the ordinary range of vision of persons in the room. This is not so necessary when lamps are placed at the ceiling, although even in the latter case lamps with frosted bulbs should be used. The question naturally comes up whether the lamp at the ceiling in a reflector is as efficient a method of lighting a room as a lamp placed lower on a pendant in a diffusing and directing globe. This test settles this point in favor of the ceiling arrangement. For another test similar to this see Test No. 13.

Test No. 7 has in the left room a lamp placed upright in the Holophane open shade, shown in Fig. 97. In the right is a bare incandescent lamp upright. The illumination on the floor is considerably better in the left-hand room, indicating a method by which the downward illumination can be increased on fixtures having upright lamps.

Test No. 8 has in the left room a lamp in a cylindrical desk shade, shown in Fig. 61, and in the right an aluminum parabolic half reflector, shown in Fig. 59. The amount of light with the parabolic reflector is greater both in area and intensity than with the cylindrical reflector.

Test No. 9 shows in the left-hand room the prismatic reflector shown in Fig. 36, and in the right-hand room the prismatic reflector shown in Fig. 34. This test shows the marked difference in light distribution with different types of prismatic reflectors and emphasizes the necessity of selecting the reflector which will give the proper distribution in any given case.

Test No. 10 shows in the left-hand room an opal bell reflector (Fig. 24), pointed at an angle of 45 degrees to the left of vertical, and in the right-hand room a bare lamp pointed at an angle of 45 degrees to the right of vertical. In both cases it is seen that considerably more light than is necessary is going to the ceiling.

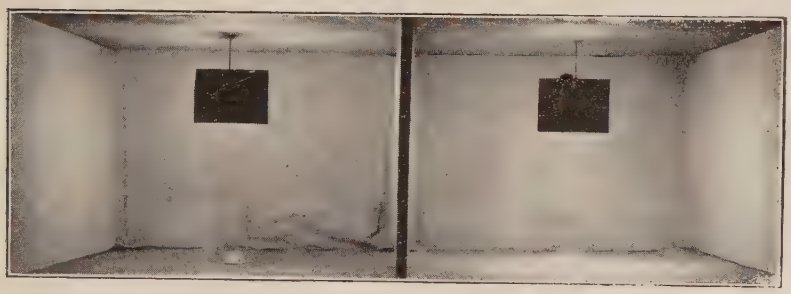


Left No. 10
Bare lamp.

Right No. 17
Fluted opal cone.

Showing great difference in the amount of light thrown down by the use of the opal cone reflector as compared to no reflector.

Test No. 1.

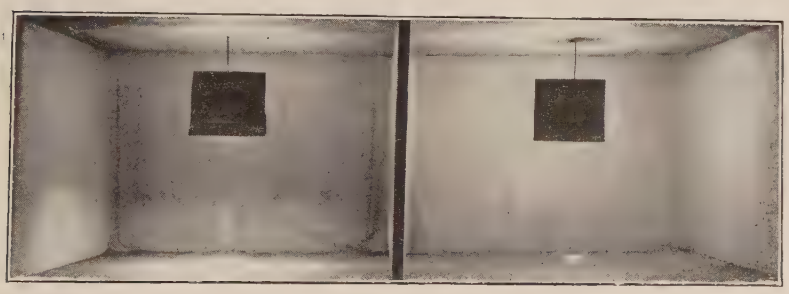


Left No. 10
Bare lamp.

Right No. 11
Pagoda reflector No. 2301.

Showing how light from a bare lamp can be modified to throw much more useful light downward without seriously darkening walls and ceilings.

Test No. 2.

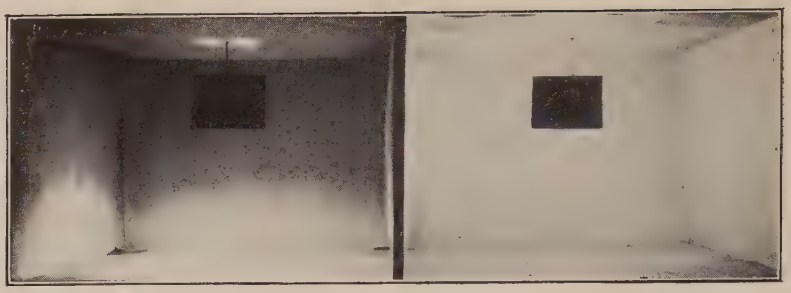


Left No. 21
Pagoda reflector No. 2651.

Right No. 10
Bare lamp.

Showing way in which amount of light given out in different directions can be changed by use of a reflector. This is a rather extreme case.

Test No. 3.

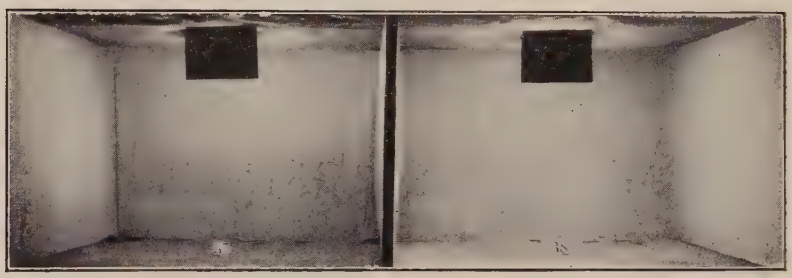


Left No. 15
X-ray desk shade No. 696.

Right No. 10
Bare lamp.

Showing an extreme case of directing light in a certain direction for special purposes.

Test No. 4.

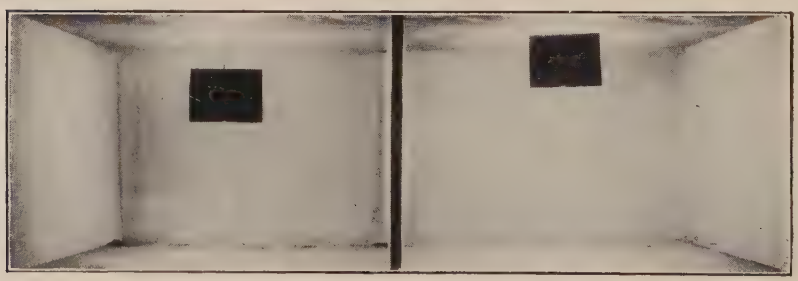


Left No. 37
Ground glass hemisphere on ceiling

Right No. 38
Holophane hemisphere No. 750 on ceiling.

Showing relative efficiency of two common methods of illumination.

Test No. 5.



Left No. 23
Holophane Class A globe No. 3363 on pendant.

Right No. 11
Pagoda reflector Class B No. 2301 at ceiling.

Showing reflector at ceiling to give more light underneath the lamp than even a Class A Holophane, and also to give better illumination of the room.

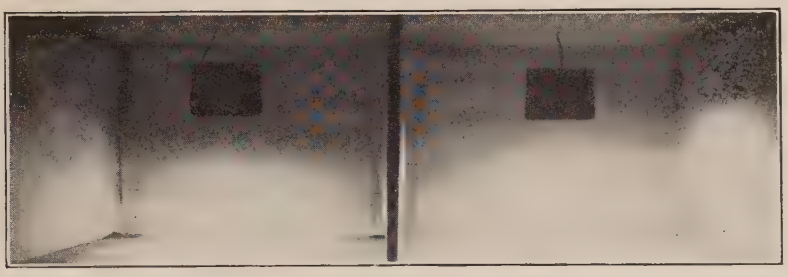
Test No. 6.

Left No. 31
Holophane open shade No. 2805 Class B upright.

Right No. 30
Bare incandescent lamp upright.

Showing easy way of improving general downward distribution of light on fixtures with upright lamps and also on gas burners. Bare incandescent or gas lamp throws most light to the ceiling and upper walls.

Test No. 7.



Left No. 27
Cylindrical desk shade, coated with aluminum, painted inside, placed horizontally as in practice.

Right No. 26
Aluminum parabolic half reflector, frosted, placed horizontal, as in practice.

Showing general superiority of parabolic aluminum reflector.

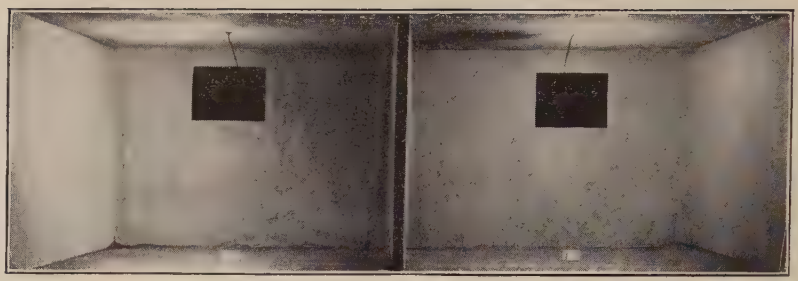
Test No. 8.

Left No. 21
Pagoda reflector Class A No. 2651.

Right No. 11
Pagoda reflector Class B No. 2301.

Showing difference in two classes of reflectors and the necessity of care in selection for any given purpose.

Test No. 9.



Left No. 12
Opal bell at angle 45 deg.

Right No. 13
Bare lamp at angle 45 deg.

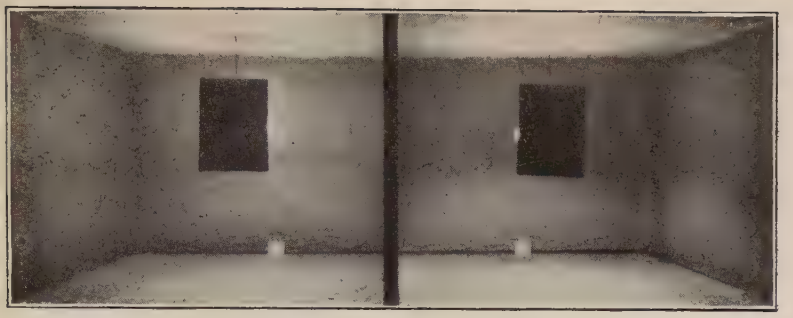
Test No. 10.

Left No. 11
Pagoda reflector No. 2301 3 ft. above floor.

Right No. 55
Stand lamp with decorated opal dome about 11 inches diameter.

The area occupied by an ordinary table is indicated by the lines drawn on the floor of the right-hand room. This illustrates how much larger an area of useful reading light is obtained with a good reflector, pointing down on a chandelier than by a table lamp, unless the book to be read is placed on the table almost against the lamp. The lamp in the prismatic reflector on the chandelier illuminates the whole room much better than the stand lamp.

Test No. 11.



Left No. 56
10-inch sand blasted dome.

Right No. 52
10-inch opal dome.

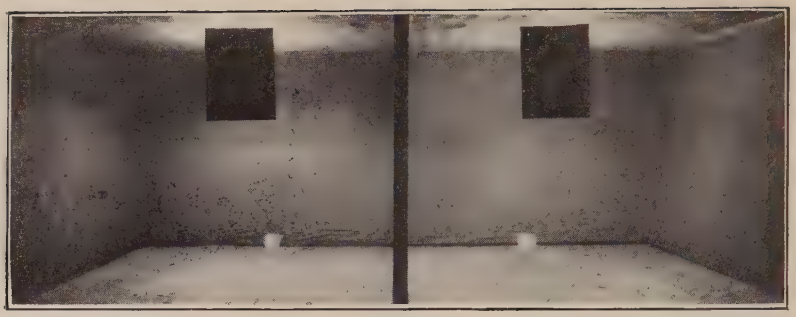
Test No. 12.

Left No. 11
Pagoda reflector No. 2301 at ceiling.

Right No. 49
Pagoda reflector No. 7381 on a pendant.

This shows Pagoda No. 7381 on a pendant to be superior for the general lighting of the lower part of the room. Pagoda No. 7381 is deep enough so that when on a pendant but little of a 16-c.p. lamp filament comes in the ordinary line of vision of a person seated anywhere in the room.

Test No. 13.

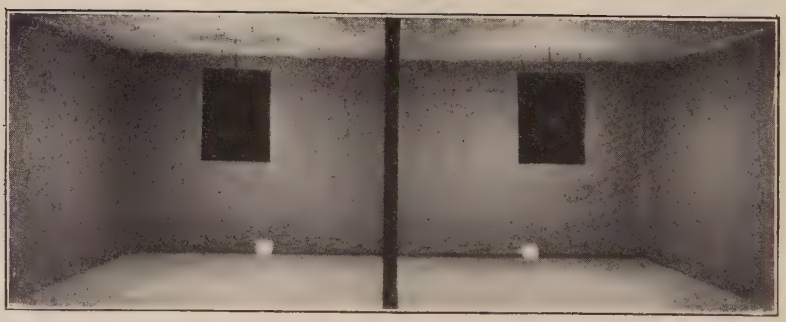


Left No. 50
Opal 7-inch dome at ceiling.

Right No. 49
Pagoda reflector No. 7381 at ceiling.

The corners of the room are better lighted by the No. 7381 Pagoda, although the light immediately under the opal dome is better.

Test No. 14



Left No. 53
Holophane Class B stalactite.

Right No. 54
Crimped opal bell with frosted bulb lamp.

This test was made to determine the relative efficiency of two equipments which give a very similar distribution of light with both of which the light from the bare filament is diffused and softened.

Test No. 15.

It is evident that with such an opal bell reflector the socket should be pointed straight down instead of being placed at an angle of 45 degrees, as is common on chandeliers.

Test No. 11 has in the left room the prismatic reflector shown in Fig. 34, and in the right a table lamp with a decorative opal dome reflector, 11 inches in diameter. This table lamp is shown in Fig. 203, and is of a more efficient type for reading purposes than the average electric portable table lamp, for the reason that the opal dome reflector tends to throw light sideways beyond the edges of the table. The lamp in the reflector in the left-hand room is at a height above the floor that the ordinary chandelier lamp would be above the reading page of a person

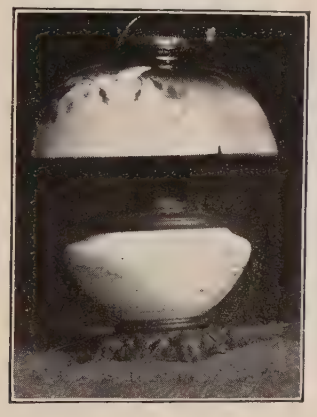


FIG. 203.

seated under it. In such a case there would be no table under the chandelier and persons reading would sit in the well-lighted area, getting the full benefit of the light. The table lamp in the right-hand room being on the floor is, of course, directly comparable to the stand lamp on a table, if we consider the floor as representing the height of a reading page of a person seated around the table. The space occupied by the table is indicated by lines drawn about the lamp. It is seen that a much larger area of useful reading light is obtained with a good reflector pointed straight down on a chandelier than by a table lamp, unless the book to be read is placed on the table almost against the lamp. The lamp in the prismatic reflector on the chandelier

also illuminates the whole room much better than the stand lamp.

Test No. 12 has in the left-hand room a ten-inch sand-blasted dome reflector, and in the right-hand room a ten-inch opal dome. The general shape of these reflectors is similar to that seen in Fig. 22, although the reflectors in this test were larger in diameter. This test shows the relative reflecting powers of sand-blasted and opal glass. The opal dome throws much more light on the floor than the sand-blasted dome, but of course robs the side walls and ceilings. In some cases the distribution from the sand-blasted dome would be preferable and in other cases that from the opal dome.

Test No. 13 has in the left-hand room the prismatic reflector, shown in Fig. 34, and in the right-hand room the prismatic reflector shown in Fig. 38. The reflector in the right-hand room is deep enough to hide the lamp filament when put on a pendant, and consequently was so placed. The other reflector in the left-hand room being shallow was placed at the ceiling to get it out of the ordinary line of vision. The whole floor area is better lighted in the right-hand room since the reflector used gives a wide distribution. The results of this test should also be considered in connection with test No. 6, where the same reflector was used on the ceiling and the conclusion was drawn that with the glassware used in that test better efficiency could be secured by the reflector on the ceiling than by the diffusing globe on a pendant. In this case, however, we see that this particular type of deep reflector on a pendant is more efficient than the reflector at the ceiling, as far as the lighting in the lower part of the room is concerned, but it must be remembered that when the general illumination of a room is wanted rather than specific lighting for reading purposes, it is desirable to throw considerable light around the lower side walls for lighting pianos, bookcases, etc. In most cases the reflector in the right-hand room (Test No. 13) will not give sufficient light at such points. The same can be said of the reflector in the left-hand room. For this reason it is usually better to use a diffusing globe on a pendant for such general lighting or else to place at the ceiling a reflector giving a distribution similar to that shown in the right-hand room.

Test No. 14 has in the left-hand room at the ceiling a seven-

inch opal dome, shown in Fig. 22, and in the right-hand room at the ceiling the prismatic reflector shown in Fig. 38. Both these reflectors, when at the ceiling, give good results for the general illumination of a room, including both the center and side walls. The opal dome gives a little more immediately underneath, while the prismatic reflector gives more around the lower side walls. Both these reflectors are good for the purposes just outlined.

Test No. 15 has in the left room a Holophane Class B stalacite, designed to give a general illumination below the horizontal seen in Fig. 81, and at the right the crimped opal bell, shown in Fig. 24, with a frosted bulb lamp. This test shows what might be expected from the photometric tests of these two different pieces of glassware, namely, that the distribution of light is very similar. Both these arrangements are well suited to the general lighting of small rooms where light is wanted in all directions below the horizontal. In both cases the light is well diffused, although the diffusion secured with the globe is better than that with the frosted bulb lamp.

In looking over these tests no attempt should be made to compare the light shown in a certain room in one test with the light shown in a certain room in another test, for the reason that there are always unavoidable differences in photographs which cause variations in the apparent amount of light in one test as compared to another. Comparisons should be made only between rooms side by side in the same test.

CHAPTER XIV.

COMPARISON OF ILLUMINANTS.

In comparing different illuminants one must consider the questions of economy, convenience, steadiness, cleanliness, safety and color. As to economy, the following table for electric light gives the total amount of light obtained or mean spherical candle power hours per kilowatt hour for various electric illuminants. This figure is obtained by dividing the mean spherical candle power of the illuminant by the kilowatts required to operate it. The mean spherical candle power of the illuminant was taken from tests made with clear glassware without reflectors in every case. The same is true of the second table, which gives the mean spherical candle power hours per cubic foot of gas per hour for various gas burners.

In considering the tables allowance must be made for a number of things. The mean spherical candle power without diffusing globes or reflectors represents simply the total amount of light produced. The amount that is delivered where it is wanted is another matter. In order to deliver the light where it is wanted and to soften and diffuse it, reflectors, shades or diffusing globes are necessary in almost every case, and there is a certain amount of loss in so reflecting and diffusing the light. This loss will of course be less with illuminants which naturally give a large percentage of their light below the horizontal (where it is usually wanted) than with those which do not. Thus the Nernst lamp and the inverted gas burner have an advantage at the start over other illuminants, as can be seen from the light distribution curves shown in the chapters treating them. Likewise also the direct current arc lamp has an initial advantage over the alternating current arc lamp. These differences in distribution can be more or less corrected by reflectors, as has been shown, but the nearer the desired distribution we have to start with the less light must be reflected and consequently the less will be the total loss in the process of reflection.

The initial efficiency of the larger sizes of electric arc and Nernst lamps is higher than for the smaller sizes, but this fact is likely to deceive the novice as to the possible practical efficiency of the various sizes. All of the smaller lighting units, because they can be placed nearer or over the areas to be lighted, even though of lower efficiency than the larger ones, can, if properly

COMPARISON OF ELECTRIC ILLUMINANTS WITHOUT REFLECTORS AND WITH CLEAR GLASS GLOBES.

Kind of Lamp.	Mean Spherical Candle Power.	Watts per Mean Spherical Candle Power.	Amount of Light per Kilowatt Hour or Mean Spherical Candle Power Hours per Kilowatt Hour.
Common 56 watt carbon filament incandescent lamp rated at 3.5 watts per candle; 16 horizontal candle power.....	13.2	4.24	236.
Common 50 watt carbon filament incandescent lamp rated at 3.1 watts per candle; 16 horizontal candle power.....	13.2	3.78	264.
Direct current 3.5-ampere enclosed arc on 110 volt circuit, 0.5 inch carbons.....	110.	3.50	285.
3-glower 264 watt Nernst lamp.....	81.0	3.26	307.
High-efficiency, Gem, 125-watt graphitized carbon filament lamp of 50 horizontal candle power.....	40.7	3.07	326.
44 watt tantalum lamp 22 rated horizontal candle power.....	16.0	2.75	364.
Alternating current enclosed 5.7-ampere arc taking 388 watts on 110-volt circuit, 0.5 inch carbons.....	152.	2.55	392.
Direct current 5.1 ampere enclosed arc on 110 volt circuit, 0.5 inch carbons.....	213.	2.63	380.
Luminous 8 ampere arc, 440 watts, 2 in series on 110-volt circuit.....	1020.	0.431	2320.

placed and properly equipped with reflectors, give fully as much useful illumination for a given expenditure for current as larger lamps. It is not always feasible to distribute them as thoroughly as would be necessary to obtain these results, hence if the outlets must be few for any reason, the larger lamps will give better

efficiency. The advertising value of the larger units in a store must also be considered.

In comparing the gas arc with individual burners it must first be noted that the efficiency of the gas arc lamp is somewhat less, as was shown by the table. We should also note here again that, generally speaking, better distribution and therefore more efficient lighting can be obtained with small units, because when such small units are equipped with the proper shade or reflector we can obtain more uniform lighting at a less expenditure of energy. However, it is not always desirable to do this,

COMPARISON OF GAS ILLUMINANTS WITH CLEAR GLASS GLOBES.

Kind of Lamp.	Mean Spherical Candle Power.	Cubic Feet of Gas per Hour per Mean Spherical Candle Power.	Amount of Light per Cubic Foot of Gas or Mean Spherical Candle Power Hours per Cubic Ft. of Gas per Hour.
Open gas, 5 cubic feet per hour at 1.5 inch water column pressure.....	20.	0.250	4.0
Gas arc, 21 cubic feet per hour at 1.5 inch water column pressure.....	325.	0.065	15.5
Upright standard mantle burner 3.7 cubic feet per hour at 1.6 inch water column pressure.....	63.	0.0588	17.0
Inverted burner, 3.0 cubic feet per hour at 1.5 inch water column pressure.....	54.	0.0556	18.0

inasmuch as a large source of light, such as a gas arc, is often an advertising feature and when limited to a few outlets the gas arc may be better than a chandelier equipped with a number of burners, on account of space occupied and cost of installation. Generally speaking, however, it is safe to say that the gas arc is a much more expensive proposition to use than the individual burners properly placed. There are so many factors, however, entering into the problem, such as maintenance and first cost (as in many cases the gas company installs and maintains the arc free of charge), that each case must be decided on its own merits. A gas arc is apt to receive much better care than a

number if individual burners and the lower efficiency of the arc may be offset by the superior condition in which it is kept.

As to color of light, the direct current electric arc lamp with small carbons enclosed in dense opal inner and outer globes, approaches most nearly to daylight of any of the illuminants enumerated; that is, it gives very nearly white light. The enclosed arc as ordinarily used has an excess of violet rays in its light. The gas mantle burners, some of which approach very near to white light, have a slight preponderance of green, which causes the ghastly effect sometimes complained of with these burners. The Nernst lamp has considerably more yellow in its rays than daylight, although it is whiter than the ordinary incandescent lamp. The ordinary electric incandescent, the open gas jet and the kerosene lamp are very similar in color, the light being decidedly yellow as compared to daylight. A short discussion of the question of the color of artificial lights is taken up in connection with store lighting.

It is well to bear in mind in the case of all these illuminants that the tests given in this book represent approximately the best working conditions with new lamps. The tendency of all is to fall off in efficiency with age.

Gas mantle burners in practice, in the hands of ordinary users, are frequently not adjusted to give the best results.

Incandescent electric lamps are frequently used after their efficiency has fallen off 30 or 40 per cent. from blackening and other causes.

Steadiness is an important quality to secure in an illuminant. Those most likely to be unsteady are open gas jets and arc lamps. These will usually flicker some no matter how steady the source of supply. Other electric and gas lamps are steady as long as the supply is steady, as it is in the majority of cases.

The consumption of the mercury vapor lamp is not obtainable in reliable figures at present writing, but as stated in the chapter on that subject, the best lamps of this type probably consume as low as one watt per mean spherical candle power. The light from mercury vapor lamps as it comes from a long tube surface does not produce dark shadows or as much annoying glare from papers or tools as would carbon arc lamps of similar candle power unless the latter had very large reflectors and diffusing globes. The absence of red rays and the greenish blue

color of the light would be extremely objectionable in some places, but in places where it is not necessary to judge of color and where a good light to work by is the principal object, the color apparently is no drawback to its use after once the users become accustomed to the strange light.

CHAPTER XV.

INTRODUCTION TO PRACTICAL EXAMPLES.

In the following chapters of this book the discussion is taken up of a large number of practical examples of lighting arrangements, both good and bad. The authors believe that by this method a much clearer idea of what constitutes good and bad design can be obtained than by a discussion of abstract general principles. Attention is called to the fact that nearly all of the photographs illustrating these practical examples were necessarily taken by daylight for the reason that the halation of a photographic plate by artificial light shining in the camera would prevent photographs being taken which would show the position, design and equipment of fixtures. The photographs from which the engravings were made are therefore illustrations of lighting design and arrangement and are not illustrations of lighting effects produced.

Before going into a discussion of these practical examples in detail, it will be of advantage to state some of the general principles which govern the design of good artificial lighting.

The difference between light and illumination should be carefully noted. Light is a cause, illumination an effect. An object on which light falls becomes illuminated. Illumination, therefore, is the result produced by light. The object of artificial illumination, except where it is purely decorative, is to enable us to see things. An object is well illuminated when it can be easily seen without fatigue or strain on the eyes. As the eye is the organ with which we are enabled to see when there is proper illumination of the objects we are looking at, it is of first importance to consider all artificial illumination with reference to its effect on the eye, and it is well to consider carefully the essentials of good illumination and the things to be avoided, as noted in the chapter on Light and the Eye.

Those desiring information on the amount of light to be pro-

vided for the illumination of large rooms should consider not only the data given in the following chapters on Practical Examples, but also the information on the Calculation of Illumination to be found in Chapter IV. It should be remembered that the small rooms in small and moderate sized residences come in an entirely different class from large rooms as regards the amount of light that must be provided. In residences the reflection from ceilings and walls plays a much more important part than in large rooms. If the suggestions made by the authors as to the location and equipment of fixtures for residences are followed, it is an easy matter to increase or decrease the candle power of the lamps to meet the personal tastes of the owners or occupants. In the calculation of illumination for large halls and public buildings it is always well to remember that at some time the building may be decorated in very dark colors, and provision should be made to take care of the very worst conditions that could arise.

In presenting these practical examples the authors have attempted as far as possible to cover all classes of lighting from the cheapest to the most expensive. That some of the arrangements illustrated are crude is fully realized, but they represent the best that can be done with a limited amount of money to be expended in lighting fixtures.

The authors wish to put in a plea for more rational fixture design. The plan in the past has been to first design the fixture and afterwards put the lamp on to accommodate the fixture design. The exact reverse of this should be the practice. The desirable location, angle and equipment of lamps should first be determined and the fixture should be designed or selected accordingly. A fixture should be first of all useful, and after that as ornamental as the pocketbook of the purchaser cares to make it. In this connection, attention is called to the fact that in the great majority of cases for which electric chandeliers are used the time-honored custom of placing lamp sockets at an angle of about 45 degrees is not as desirable as placing the sockets pendant; that is, pointed straight down. With sockets pendant there is opportunity for much greater range in the selection of satisfactory glassware and glassware can be selected which will give a uniform distribution in all directions from a chandelier. With sockets at an angle the choice of glassware to give good

results is very much limited and in some cases, thoroughly good results are impossible. There is, furthermore, the very serious mechanical objection to sockets pointed at an angle, namely, that the weight of shades or globes is such that frequently the shade holders bend and sag and the sockets come to pieces, due to inherent weaknesses of sockets and shade holders. This produces a very bad appearance, to say nothing of its bad effect on the illumination. With pendant sockets practically all these troubles are avoided. Wherever sockets are used at an angle, it is well to select the most rigid shade holders obtainable.

Another practical point that it is well to remember in planning the illumination of all classes of buildings is that switches should be located in sight of the lamps they are to control, thus saving confusion as well as making it more likely that lamps will not be forgotten and left burning when persons leave the room. A switch out of sight of a lamp is a prolific source of waste and dissatisfaction.

Most of the examples shown are of electrically lighted rooms, for the reason that electric light offers the greatest opportunity for proper and improper use, because of the great variety of positions in which it may be located. A sufficient number of examples of gas lighting are given to indicate the way in which gas should properly be used. Gasoline and acetylene gas lighting offer practically the same problems as common gas.

The authors have endeavored as far as possible to avoid useless discussion of matters which are largely those of individual taste and to confine their discussion to questions of illuminating engineering.

It is always to be remembered that artificial lighting is a compromise between appearances or artistic effect and economy. It is the province of the engineers and architects who understand these matters to present them to their clients in such a way that clients will understand the effect of different designs on economy. It is then for the client to determine how much economy he is willing to sacrifice for the sake of artistic effect.

Acknowledgement is due to the *Electric City*, the Chicago central station publication, for a number of excellent photographs of some of the prominent buildings in that city which are here used.

In discussing these practical examples frequent references

are made to globes, shades and reflectors upon which tests are given in the preceding chapters of this book. In the Appendix will be found the manufacturers' names and trade numbers of the various reflectors, shades and globes tested.

CHAPTER XVI.

RESIDENCE LIGHTING.

Living Rooms and Small Parlors.

As the living room in the average home is the one most occupied during the evening and hence the one about the lighting of which the occupants are most particular, it naturally comes first in a consideration of residence lighting.

The general lighting of the living rooms of small or moderate-sized residences and the provision for reading lamps in these rooms are so closely connected that they must necessarily be considered together. Reading light is likely to be used constantly and has so much to do with the comfort and eyesight of members of the family that it needs earnest consideration. There are three common ways of obtaining light which is suitable for reading. One way is to illuminate the whole room so brightly that reading is easy in any part of it. The cost of lighting a room so brilliantly as this makes it out of the question in the majority of rooms, and for living rooms is not usually considered good artistically. We will, therefore, leave out of consideration this method of securing reading light and consider the second and third methods. The second method is to use a lamp placed near the reader and fitted with a reflector which will concentrate nearly all the light on the book or paper. If this is done the reading lamp is likely to be of little value in the general lighting of the room, and other lamps besides the reading lamp will have to be added if the greater part of the room is not to be in comparative darkness. The third method, which is the one usually to be preferred where the greatest economy is an object, is to use the same lamp both for reading and for the general lighting of the room by equipping the reading lamp with a globe or reflector which will concentrate a considerable portion of the light within the area in which it is desired to read, and at the same time allow enough light to radiate in all directions to give fairly

good illumination over the rest of the room. There is a popular impression that the portable table lamp is better adapted to reading than a lamp on a chandelier or bracket. Such table lamps are an inheritance from the days of the candle and oil lamp. With electric lamps or with mantle burners, usually much more satisfactory results can be obtained with a properly equipped reading lamp on the chandelier or on a bracket on one of the side walls. The reason for this is that it is impossible with a table lamp to secure a reflector which will throw as large a proportion of the light where it is needed for reading purposes as can be obtained from the proper reflectors on chandeliers and brackets. Most of the portable stand lamps throw the greater part of the light down on the table around the base of the lamp, so that the readers sitting around the table get only a small percentage of the light. (See test No. 11 in the chapter on Demonstration Room Tests.) Taking any of the shades or reflectors which are at all suited for use on a portable table lamp, it will be seen that this is true. The opal dome used on electric lamps, Fig. 22, or the opal dome and bobesche used on gas mantle burners, Fig. 126, are good examples of this. If the portable stand lamp is used on a library table where the readers place their books on the table each side of the lamp to read its use is permissible, but such is not the usual condition.

There is also considerable misconception as to the comparative distance from the reader of a lamp located six feet above the floor on a chandelier as against a lamp located on a table. The average person who has never measured these distances is under the impression that the lamp on the reading table is much nearer. As a matter of fact the distances are nearly the same. There is really for the majority of cases only about one thing to be said in favor of an electric table lamp for reading as against a properly equipped lamp on a chandelier or bracket. This is, that with the table lamp it is not as likely that a reader will get the regular reflection commonly known as the " glare " from a page of white paper because the light comes so much from one side. In reading underneath a lamp on a chandelier or bracket the reader must turn the page at such an angle that he does not receive this glare from the paper. This is easily done, but many people undoubtedly suffer from this without knowing what is the trouble or taking the pains to find out.

Since this glare is likely to be more pronounced with electric lamps and mantle burners than with kerosene lamps, it is probable this that is partly responsible for the preference that some people have for oil reading lamps, even though electric light is available in the rest of the house.

The light intensity per square inch of the incandescent lamp filament is much higher than that of the kerosene lamp flame, hence the glare from the paper is more concentrated and intense. The electric lamp can be reduced to an equality with the kerosene flame in this respect by using a frosted bulb.

In what has been said as to the advantages of reading lamps placed on chandeliers and brackets as against an electric table lamp, it must be carefully noted that the authors do not advocate trying to read with light from chandeliers which are arranged entirely for the general illumination of the room. Chandeliers should be equipped with reference to using them for reading, if they are to be superior to electric or gas portable table lamps.

The authors have also neglected here the consideration of a portable reading lamp equipped with an art glass or other fancy shade, the primary use of which is for ornamental purposes, and secondarily for reading. Such shades are taken up later in this chapter.

The following illustrations are from photographs taken by daylight to show the arrangements of fixtures, etc., and do not attempt to show the illumination of the room by artificial light.

In Fig. 204 is shown one of the best arrangements of chandelier for a small living room where a good reading lamp and lamps for the general illumination of the room are provided on the same fixture. On this chandelier a middle socket which points straight down is equipped with a prismatic glass reflector, which concentrates light under the chandelier for reading purposes and at the same time allows enough light to escape through the reflector to illuminate the walls and ceilings moderately so that the single reading lamp is sufficient ordinarily, both for reading and general illumination of the room. This arrangement giving moderately illuminated walls and ceilings will be satisfactory to most people, but there are some who for artistic reasons or because of weak eyes will prefer to have the walls and corners of the room darkened more than this. It is easy to accomplish this darkening by placing

an ornamental silk covering over the reflector or by using a decorated opal reflector which obstructs most of the light that it does not reflect. In this way the brightly lighted reading area and darkened room corners that some think so cosy and cheerful a feature of table lamps can be obtained. As to whether this

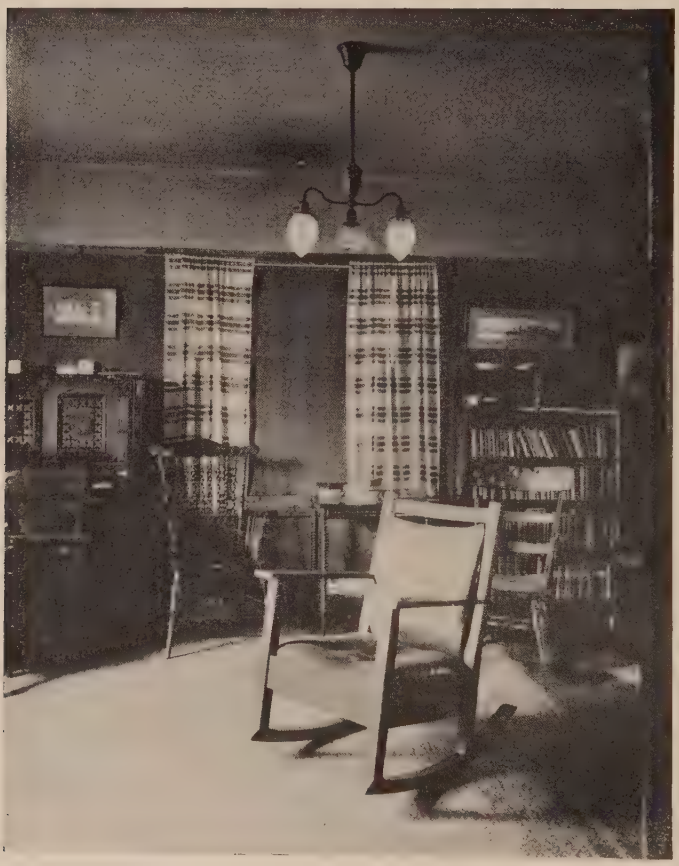


FIG. 204.—One of the best arrangements for small living room.

darkening of the corners is desirable, is largely a matter of personal taste. There is no doubt such a thing as carrying it too far for the good of the eye sight. While it is desirable to rest the eye occasionally while reading with artificial light by glancing from the brightly lighted page to parts of the room not so brilliantly

illuminated, it is not good to have this change too violent. Thus, suppose, for example, a person is reading under an opaque concentrating reflector. The light on the reading page will be very strong, and the balance of the room, especially if it has dark rugs and walls, will be almost in darkness. A change from the brightly lighted page to the dark corners of the room is extremely violent and is a strain on the eye, although a change less violent would be a helpful rest to the eye. It is also undoubtedly true that the eye is more comfortable when receiving a moderate amount of light from all directions, as it does in daylight than when getting all its light from a bright page in a dark room. The particular reflector shown on the center socket in Fig. 204 (the light distribution of which is shown in Fig. 33) concentrates its light over a floor area sufficiently large to permit four persons to read comfortably under it.

Larger or smaller reading circles can be obtained by using more or less concentrating reflectors. If only two persons use this chandelier for reading a deeper and more concentrating reflector covering the lamp more completely is advisable, thus accomplishing the double purpose of getting a stronger light immediately under the chandelier and shading the bare lamp filament from any who may be seated around the room looking toward the chandelier while the center lamp is turned on. For a very large reading circle, the center socket should have a reflector giving a distribution like that shown in Fig. 37 and if that particular reflector be used it will also shade the lamp from those seated around the sides of the room. On special occasions or when there are visitors, when the general illumination of the room rather than a concentrated light is wanted, the two lamps on the arms of the chandelier are lighted and the center lamp put out. These chandelier arms are equipped with globes which give a good general distribution of light in all directions below the horizontal similar to that shown in Fig. 80 and also diffuse the glare from the lamps to make the light comfortable to visitors and others who may sit facing it. The same general scheme could manifestly be used with a chandelier having three or four arms carrying lamps for the general illumination of the room. The chandelier as it stands in Fig. 204 is in a room 14 feet square with dark walls and rugs and is equipped with eight candle power lamps in the arm sockets and a 16-candle power

in the center socket for reading. This candle power can, of course, be increased at the desire of the user. In a light colored room of this size, lamps of this candle power would be more than sufficient, but may not suit all tastes in a room with dark walls. The centre or reading lamp is not used when general illumination is desired, and vice vèrsa, the lamps for general illumination may usually be turned off when the reading lamp is on. If an especially strong concentrated light is wanted an attachment plug with a 16-inch drop cord can be hung from the middle socket so as to bring the lamp about one foot above the head of a person seated under it. With a good concentrating type of reflector on the end of the drop cord, this makes an excellent arrangement for sewing on dark goods at night or any work requiring an extra strong light for one person. Many modifications of Fig 204 suggest themselves. For the general lighting of the room Class B Holophane globes were chosen in this case, as before explained, because they give the proper distribution of light below the horizontal and at the same time diffuse the light so that persons sitting around the room in general conversation are not annoyed by the glare from the bare filaments of the lamp. The same purpose could be accomplished in a different way by selecting some type of reflector which would give a good intensity in all directions below the lamp and using lamps with frosted bulbs inside the reflectors. (See Test 15 in the chapter on Demonstration Room Tests). The opal bell with crimped edge, Fig. 23, probably comes the nearest to these requirements as far as distribution of light is concerned. In such a case, the center reading socket should preferably be an opal dome or cone to harmonize. It is important to remember in the general lighting of a living or reception room where a number of people are likely to be sitting around in positions facing the chandelier to avoid anything which would allow the undiffused rays from a large portion of the bare filament of a lamp to fall in the eyes. For this reason, whenever open reflectors are used, they should be equipped with frosted bulb lamps. On a chandelier like that shown in Fig. 204, if the reading lamp does not have a frosted bulb, it ought to be turned off when general illumination on special occasions is desired. It will be noticed that the sockets on the arms of the chandelier, Fig. 204, are placed pen-

dant, or pointing straight down. With a globe or reflector giving a similar distribution of light to that in Fig. 23 and 80 an angle of 10 degrees from the vertical should not be exceeded with these sockets, otherwise an unnecessary amount of light will be thrown up toward the ceiling and high side walls.

Another good way to provide for reading and general lighting in a small living room is to place a hemisphere in the middle of the ceiling for general lighting and for reading to put in one or two wall brackets. The hemisphere should be equipped with a reflector inside as recommended in the chapter on clusters and bowls for incandescent lamps. The reading bracket should have its lamp pointed at from 30 to 45 degrees from the vertical and should be equipped with a reflector according to suggestions made for the reading lamp socket on the chandelier in Fig. 204.

In Fig. 205 is shown a good example of how not to arrange a reading lamp. Here the portable table lamp is attached by an extension cord to one of the sockets on a chandelier. The table lamp like most of its kind, throws the better part of its light on the table, while the persons reading are supposed to sit around the table at some distance from the lamp. The extension cord from the chandelier is a nuisance and unsightly. This chandelier could be easily converted to afford an efficient reading light by replacing the wastful opal ball on the bottom of the chandelier by a reflector or globe for throwing light down. If a number of persons were to read under the chandelier, an opal dome reflector (Fig. 21) with a frosted lamp could be used to advantage, as it would throw light over a considerable area, supposing that the other glassware on it were changed to harmonize. Returning to Fig. 205, the opal bell reflectors on the three arms of the chandelier are excellent for the particular purpose of general illumination in this particular room. When placed at an angle of 45 degrees, as on this chandelier, they throw considerable light to the high side walls and illuminate the pictures which are placed high. They should be used with frosted bulb lamps. In the majority of cases, the arms of this chandelier, Fig. 205, if equipped with opal bell reflectors of this kind should have sockets pointed nearly straight down, otherwise too much light goes to the high side walls On this chandelier, as it is shown, the opal ball on the bottom absorbs a large percentage of the light and does not direct the rays in useful directions.

Fig. 206 is an example of a common arrangement of chandelier for parlor and living room lighting. Its greatest defect is that no provision is made for reading lamps unless they be attached in place of the lamps in one of the sockets, which is an unsightly and unsatisfactory arrangement. Where such a

FIG. 205.—Poor arrangement of reading lamp.

chandelier is used in a living room, provision should be made for a reading lamp on a side bracket, but it is too frequently the case that it is not made. The chandelier in Fig. 206, when equipped with fluted opal cone reflectors of the type shown in Fig. 19, placed at an angle of 45 degrees, will, on a three light chandelier in the middle

of a square room, as in this case give an excellent distribution of light for the general illumination of the room. Frosted bulbs should always be used in them when so placed in order to avoid the glare in the eyes of the occupants. A general illumination of a room is usually wanted only at times

FIG. 206.—Common chandelier for small parlor.

when a number of people are using a room, and it is at such times that some are sure to be sitting facing the light. To throw the light from a strong reflector in the eyes of the guests, in addition to the undiffused light of the bare incandescent lamp filament is anything but hospitable treatment, and in the course of an

evening will cause discomfort, although its cause may not be apparent to the person effected.

Fig. 207 shows how good reading light was obtained from a chandelier like that in Fig. 206. A short length of drop cord was attached to one of the sockets and a reflector harmonizing

FIG. 207.—Making the best of bad design for reading purposes.

with those on the chandelier was hung pendant, as seen, so that it throws its light directly down. This, of course, is a makeshift, but is intended simply as a suggestion as to how to make many existing arrangements tolerably satisfactory. The chandelier was equipped with etched glass shades. The reading

lamp was placed in a prismatic glass reflector giving a distribution similar to that shown in Fig. 35, and the light for reading under the chandelier since the change is far better with one 16 candle power lamp, than it was formerly with three lamps

FIG. 208.—Arrangement for small room.

on the chandelier arms, although, of course, the general illumination is not as good.

Fig. 208 shows a good chandelier arrangement for both reading and general illumination in a room where, as in a small library the light is used almost entirely for reading and persons

are rarely seated anywhere but under the chandelier. This is simply a two-lamp chandelier with both sockets vertical, equipped with the prismatic reflectors shown in Fig. 33. This concentrates enough light for reading in the center of a room while giving good

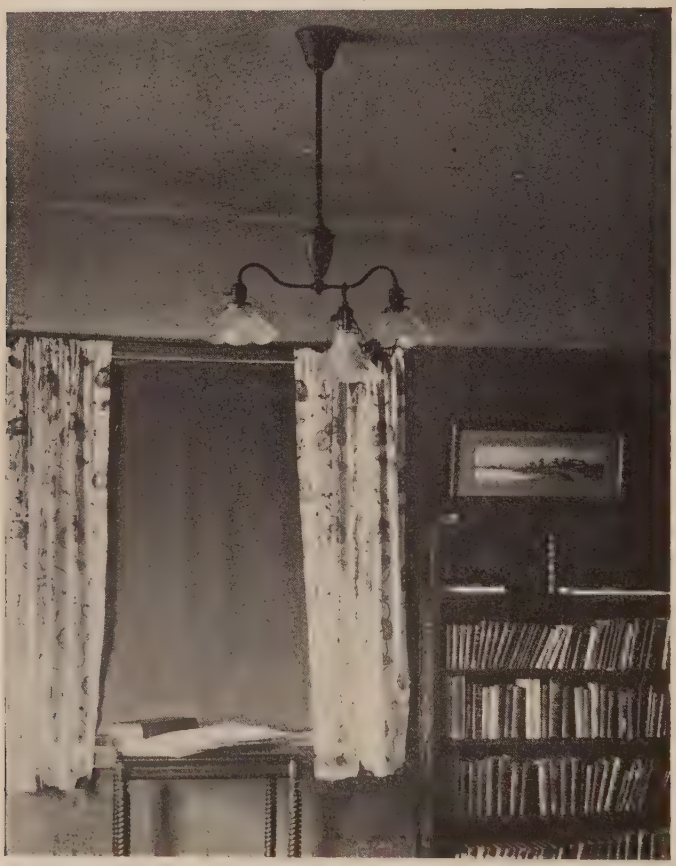


FIG. 209.—Arrangement for concentrated illumination.

enough illumination for ordinary purposes in the far corners. These reflectors give their concentrated light over a fairly wide area as compared with many others of this type. If a more concentrated light is desired, an attachment cord and plug can be put on as in Fig. 209. This attachment equipped with a power-

ful concentrating reflector can be used either hung up on the chandelier, as shown, or let down for sewing or work requiring intense light. This chandelier is not as good an all-around arrangement as that of Fig. 204 as it does not provide as well for the general illumination of the room. The reflectors nearly cover

FIG. 210—Poor arrangement for reading lamp

the lamp bulbs so that not much of the bare lamp filament is visible to a person seated in one corner of the room. Even this little is objectionable, and it would be better to have it covered by using a frosted bulb lamp.

Fig. 210 is another good example of how not to do it. The read-

ing lamp located on the table equipped with a downwardly pointed socket and opaline fluted cone shade throws nearly all its light on the table. The absurdity of trying to read by such an arrangement can be seen by consulting the test given in Fig. 19 showing the light distribution from a somewhat simliar reflector. The

FIG. 211.—Effective reading light on bracket.

absurdity of the arrangement is further emphasized by the presence on the wall immediately back of the reading table of a bracket with a socket pointed at just the right angle to throw a good light for reading purposes.

Fig. 211 shows how the arrangement in Fig. 210 was converted

into a very efficient reading arrangement by simply putting a good concentrating type of reflector on the wall bracket and moving the large table away so that those desiring to read could sit within the range of the concentrated light from the reflector on the bracket.

FIG. 212.—Good arrangement for small room.

Fig. 212 shows a good way of lighting a small parlor with a chandelier having sockets at an angle of 45 degrees. This is a similar case to that shown in Fig. 206. No concentrated light was wanted in any portion with the possible exception of the piano, and for this, sufficient light is obtained from the chandelier.

The chandelier is equipped with three globes, such as shown in Fig. 79, these being designed to concentrate much of the light in the direction in which the tip of the lamp points. This chandelier in Fig. 212 was previously equipped with opaline bell reflectors, which allowed so much of the light to escape towards the ceiling that there was not enough at the piano and in the lower part of the room. It is a mistake to equip a chandelier of this kind with any type of globe or reflector which will give a general distribution of light at a wide angle below the horizon-

FIG. 213.—Decorative inefficient table lamp.

tal unless the lamp is placed in a pendant or vertical position. With lamps at an angle and a distributing reflector too much light is directed up.

Fig. 213 is a good example of a handsome table lamp which is useful principally for decorative purposes. It has the same shortcomings as all electric table lamps, namely, the inability to throw a large proportion of its light in directions most needed, unless the light is needed on the table near the lamp. It does, however, add considerably to the artistic appearance of a room

and the authors do not wish to be understood as condemning artistic ornamental lamps of this kind. When they are used, however, it should be with a full understanding of their inefficiency for all purposes except those mentioned. There are cases where expense is of secondary importance and by equipping decorative lamps with sufficiently high candle power lamps they can be made to do satisfactory useful work. As a general thing an ornamental lamp of this kind might better be provided with a low candle power lamp and used simply for decorative purposes depending on something else for the useful illumination. Such

FIG. 214.—Expensive parlor with makeshift reading lamp.

a large lamp as that shown in Fig. 213 might have the two lamps in it fitted with small opal or prismatic glass reflectors so pointed as to throw the light where needed.

LIGHTING OF LARGE PARLORS.

The parlors illustrated under this head are mainly those of the larger class where expense is a secondary consideration.

Fig. 214 teaches an interesting lesson in the lighting of a living room. Although an abundance of outlets for electric lamps have been provided, and expense has not been spared in fixtures, the

lamps have evidently been placed in opal enclosing globes which absorbed so much light that the owner has been obliged to resort to a makeshift for reading purposes and has purchased a desk lamp with the type of desk shade shown in Fig. 57. This shade, when placed on this type of portable fixture is very good for one person to read by, but in a room of the character of that shown in Fig. 214 a makeshift like this should not be necessary. A central socket should have been provided on the chandelier on which a reflector in keeping with the fixture could have been placed. It would have been better, in any event, to use sand

Fig. 215.—Living room with upright lamps.

blasted or frosted balls on the chandelier instead of opal. If this had been done, it would probably have been unnecessary to provide any special reading lamps unless economy of operation were an object.

Fig. 215 shows a large parlor equipped with upright electric lamps in frosted globes. The fixture designers have been careful to place a cup under each lamp as they have under each imitation candle gas jet, an absurdity in design both as to looks and utility. This tallow cup cuts off considerable downward light. The use of upright lamps here may be artistic, but could not be urged as an economical design. Fully as

artistic designs can be obtained in downwardly pointed lamp sockets and the results in lighting the room will be much better. Where upright electric lamps are used, the only way of increasing the downward illumination and at the same time adhering to the use of enclosing globes is to use a diffusing and directing globe such as shown in Fig. 85. If the owner much prefers upright to pendant lamps it is permissible to use them providing they are used with the full understanding that more light must be provided than with pendant lamps and that the cost of satisfactorily lighting a room will be greater.

FIG. 216.—Living room with dome fixture.

Fig. 216 shows a method of living room lighting which is most commonly found in dining rooms. There is an art glass dome in the center for lighting immediately around the table for reading purposes. The general lighting of the room is provided for by art glass fixtures hanging from the beams and by the round frosted bulb candle lamps on the the art glass dome. To provide a satisfactory illumination around the table for reading, the art glass dome in such a case should preferably be equipped with one frosted lamp pointed straight down, this lamp being from 32 to 50 rated horizontal candle power. Over the lamp inside of the art glass dome should be used an inverted bowl

reflector giving a distribution of light similar to that shown in Fig. 37. Such a reflector will also have the effect of obviating the streaks around the side walls which would otherwise be present, due to the light shining through the fringe on the art glass dome. The art glass dome will be more uniformly and pleasantly lighted by one large lamp in a reflector than by several lamps of lower candle power.

Fig. 217 is an example of the lighting of a large parlor which could be considerably improved. The first objection to be

FIG. 217.—Large parlor with too much glare.

urged against the arrangement shown in this figure is the great amount of glare from the lamp filaments which any one sitting in the room receives. The opaline shades on these chandeliers are of little value as reflectors and are not of a shape to act as diffusers and softeners of the light. An opal or ground glass reflector of this shape, used with frosted bulb lamps, would give much better results. The location of the fixtures in this case is very good for a parlor of this kind. Both the chandeliers and the brackets along the wall are placed high, although the chandeliers might well be placed still higher. In general, it can be said that

the results, as far as the amount of light obtained below the horizontal is concerned, would be much better in this case if any good reflector giving a large amount of light below the horizontal was selected in place of those on the chandeliers at present.

Fig. 218 is an example of lighting in a living room where expense is a secondary consideration. The ground glass globes, in which all the lamps are enclosed, diffuse the light so that the arrangement is very good from a hygienic standpoint. With

FIG. 218.—Living room well and expensively lighted.

the arrangement shown, an unnecessary amount of light is being spent on the ceiling. The proper prismatic glass reflectors over the large, spherical bulbs seen on the ceiling fixtures in the center of the room would add to rather than detract from the appearance of the fixture and would greatly increase the amount of light secured around the table and at the piano where the light is most needed. In a dark colored room of this kind it is seldom that there is any too much light thrown down in the lower part of the room for useful purposes.

Fig 219, the parlor of the Windemere Hotel, Chicago, is lighted

with lamps in ball globes such as shown in Fig. 83, the principal purpose of which is to diffuse and soften the light so as to avoid glare. Ground glass balls could be used for the same purpose but would not give quite as good a diffusion. More downward distribution of light could be obtained by certain other types of globes which modify the distribution of light from the bare lamp more than do these balls. Aside from this, the design of the lighting of this parlor is good.

FIG. 219.—Well diffused light.

DINING ROOMS.

A small dining room is probably the easiest room in the house to light. All that is necessary for ordinary purposes is to throw a strong light down on the table. The reflection from the white tablecloth to the walls assists greatly in the general lighting of the room. The main thing, however, is to have the table well lighted and the balance of the room will usually take care of itself. With electric lighting the simplest and most economical arrangement possible for a small dining-room is a plain one lamp pendant over the center of the table, equipped with some

type of reflector which will throw a large proportion of its light on the table while allowing some to escape through to illuminate the walls and ceiling.

Fig. 220 shows a simple arrangement for dining room lighting. The lamp is placed six feet above the floor, which is slightly lower than the ordinary height of chandelier. The dining room shown in Fig. 220 is about 15 feet square, and for all ordinary occasions an eight candle power lamp in the prismatic glass reflector shown is sufficient. A lamp of larger candle power could, of course, be used on special occasions if the table were length-

FIG. 220.—Simple but efficient dining room arrangement.

ened out. The particular prismatic reflector shown in Fig. 220, the distribution of which is shown in Fig. 33 concentrates a little too much light on the center of the table at the expense of the edges. One giving a wider distribution of light as shown in Figs. 21 and 37 would be desirable. This one lamp pendant idea can be elaborated into a very artistic fixture by substituting a chain for the rod and using an art glass shade as in Fig. 221. With such an art glass dome the preferable arrangement is to have one lamp pointing straight down so that a reflector giving a distribution like that shown in Fig. 37 can be placed

over it. The whole top of the table will then be evenly lighted and the fringe will be prevented from making unsightly streaks and shadows on the walls. With a deep dome it is a good plan to have a ground glass bottom on it to diffuse the light. With a large ground glass bottomed dome it is also a fairly good arrangement to put several lamps in a cluster, each lamp pointed at an angle and equipped with a small opal or prismatic reflector. On the whole, however, a larger single lamp of equal candle power pointed straight down and equipped with the right reflector

FIG. 221.—Art glass dome for dining room.

will give more satisfactory results. In Fig. 221 small deep reflectors can also be used to increase the downward light from the art glass ceiling fixtures over the corners of the room and will help eliminate the streaks due to the fringe.

Fig. 222 shows how not to light a dining room with a one lamp pendant. This pendant has the lamp placed at an angle of 45 degrees in a bell glass shade. The shade is not of the kind which greatly influences the distribution of light, and what influence it does have on the light is of no practical benefit

because of the angle at which the lamp is mounted. With the arrangement shown in Fig. 222 a 16-candle power lamp will not

FIG. 222.—Simple but inefficient arrangement for dining room.

give as good results in any given room as an eight candle power lamp with the pendant shown in Fig. 220.

Fig 223 is another example of how not to light a dining room.

It is a case of getting a large amount of light everywhere but on the table, where it is most needed. The lamps are placed at

FIG. 223.—Arrangement to be avoided.

such an angle that the light of the bare filament strikes directly in the eyes of those seated at the ends of the table.

Fig. 224 shows an excellent way of lighting a dining room

where something a little more elaborate than Fig. 220 is desired and where the room is too large to be lighted well with a single pendant. In Fig 224 the ordinary lighting of the dining room table is accomplished with the lamp within the opal dome reflector located on the bottom of the chandelier. This opal dome (See Fig. 21) gives an excellent distribution of light for this purpose and will throw light over a considerable angle so that a

FIG. 224.—Good dining room arrangement.

large table can be lighted. If additional light is wanted around the sides of the room on special occasions, the three lamps on the arms of the chandelier can be turned on. These are equipped with opal bell reflectors, (See Fig. 23) which, when placed at this angle, throw considerable light to the high side walls, lighting up the plate racks and decorations of the room. Since the occupants of the dining-room are usually seated

around the table, frosted bulbs are not as necessary in these reflectors as they would be were the occupants of the room seated where the light from the chandelier would come more nearly in the line of ordinary vision, but they are desirable nevertheless as they do away with glare and give a softer, better

FIG. 225.—Poor lighting of hotel private dining room.

diffused light than the clear bulb lamps and with but small loss by absorption.

Fig. 225, which is a view of one of the private dining rooms in Hotel Stratford, Chicago is a good example of how not to light such a room. A cluster of nine bare lamps is placed near the ceiling without reflectors of any kind. The ceiling acts

somewhat as a reflector but a very inefficient one. It is safe to say that the table and the lower part of the room in general would be as well lighted with half the number or candle power of lamps were some simple and ornamental form of reflector used. With a chandelier placed as high as this, the high side walls, upon which there are elaborate decorations, would receive sufficient light were any translucent reflectors used, while the table and the lower part of the room would receive very much more light and the artistic effects would be much

FIG. 226.—Dining table dome with upright lights.

improved. In this case frosted bulb lamps are not as necessary to pleasant illumination as where they are placed lower over a table.

Fig. 226 shows another design of art glass dome for dining room lighting. The remarks made about Fig. 221 as to the proper equipment of such art glass domes also apply here. In this case, the general lighting of the room is provided for by two frosted upright lamps, mounted on the dome. These lamps are shielded by the dome from the eyes of persons seated at the

table, which is an important point where the general lighting of the room is provided for by lamps placed so low. Another absurdity in fixture design is seen here. Round bulb lamps have been placed on a candle fixture on the dome.

Fig. 227 shows another design of dining room lighting with an art glass dome. In this case, the general lighting is accomplished by ceiling lamps in frosted globes and by frosted bracket lamps on each side of the fireplace. The design is very good. The art glass dome shields the eyes of a person seated at the table from the rays of the opposite ceiling light which might

Fig. 227.—Artistic dining room lighting.

otherwise be objectionable. The bracket lamps on each side of the fireplace are permissible in a dining room fireplace for ornamental purposes. In a living room, where people are likely to sit in front of the fireplace, lamps on each side of the fireplace are not to be recommended except where intended entirely for ornament and not for use when there is a fire, because they detract from the cheerful effect of the fire and are likely to be harmful to the eyes. To make a fireplace thoroughly cheerful the surroundings of the fireplace should not be lighted too much.

Fig. 228 shows a dining room well lighted by gas. The center arrangement is equipped with an argand burner, giving a soft mellow light, while the opal dome acts as a good reflector. The other lamps on the chandelier can be used when necessary, for general illumination of the room. The argand burner might be equipped with a frosted or Holophane bobesche to good advantage so as to protect the eyes.

It should be noticed in such cases that where a center light is used, along with other lights it is not desirable to mix the color effects of mantle burners with open gas. The argand

Fig. 228.—Good dining table lighting with gas.

burner, having practically the same color as an open flame, should be used in preference.

The examples given of dining room lighting so far have nearly all been of rooms with ceiling outlets. Side wall brackets for general lighting are employed in addition to the center lamp for the table in some modern dining rooms with good artistic effect. The lamps on such brackets since they are sure to be in the line of vision of some one sitting at the table must be well provided with diffusing globes to avoid discomfort to the persons facing them.

Bedrooms.

The lighting of bedrooms, especially in small residences where first cost must be kept low, is the most difficult problem to be met with in residence lighting. To light a bedroom properly, lamps are needed at various times in a number of places, yet it is seldom that the owner is willing to pay for as many outlets as would be necessary to provide for all contingencies. Before considering specific cases, let us see just what lamps are needed in the ordinary bedroom. The first essential is usually light at the dresser, so that a person standing in front of the dresser can have the use of the mirror without annoying shadows. To illuminate a dresser mirror perfectly three lamps are necessary although they are seldom provided. One of these three lamps should be directly above the mirror, and the other two should be located on each side about 4.5 to 5 feet above the floor.

For the side brackets on each side of a dresser, upright lamps are generally preferable for the reason that if pendants are used, considerable light is thrown down on the floor, where it is practically of no value, little of it being reflected. If uprights are used, the light thrown upwards strikes the ceiling and walls, adding to the cheerfulness and general illumination of the entire room.

The side lamps are needed to light the sides of the face of a person standing in front of the dresser and should be low enough so that there will be no shadow under the chin of a man shaving. These side lamps, if placed at this height, however, will not be high enough to light the top of a person's head so that there will be a shadow at that point, which must be obliterated by a lamp placed above the mirror for use in hair dressing. There should manifestly be some general illumination in a perfectly lighted bed room, for which purpose a chandelier or pendant, or a lamp at the ceiling in the middle of the room can be provided. In addition to this, it is desirable to provide a bracket with a chain pull socket immediately over the head of the bed for reading purposes and where it will be within easy reach of a person desiring to turn on the light in the night before getting out of bed. Besides this, if the closet is large there should be a closet lamp, although this is hardly necessary in small closets. Thus there should be five or six outlets in a perfectly lighted bedroom, which is more than in most of the other rooms in the house and

would be considered out of the question by most owners of small residences. Some compromise must, therefore, be adopted in most cases which will cut down the number of outlets or make one or two outlets available for more purposes. The use of portable brackets as described later is one of these compromises which, although undesirable from the standpoint of appearance, is nevertheless too practical and useful to be left out of consideration, especially in the wiring of old houses where one outlet in the center of a bedroom must frequently suffice for all purposes.

Another trouble usually met with in planning the lighting of a bedroom is the uncertainty as to the location of various pieces of furniture. It sometimes happens that there is only one good place for the dresser in a room, and in such a case, whoever plans the illumination can with safety and certainty place the dresser lamps with the knowledge that they will not be in the way of any future changes of furniture location the housewife may wish to make.

On the other hand it is sometimes difficult to locate brackets where they will not under some circumstances prove inconvenient and in the way of furniture. Some suggestions as to overcoming this difficulty are given later.

Where the general lighting of a bedroom is to be provided for by a central fixture, the problem is not materially different from the general lighting of living rooms and parlors, and for suggestions on this point the reader is referred to the previous remarks on that subject. The points that need special consideration in bedroom lighting here are, therefore, the lighting of dressers and the provision of bracket lamps over the beds or at other desired points.

As the lighting equipment of a bedroom depends so much on the amount that the owner is willing to spend in order to secure good lighting the simplest and cheapest plans will be taken up first and then the more elaborate ones.

The authors fully realize that some of the cheaper arrangements proposed are crude and of not very pleasing appearance but they are not any more so than some of the existing lighting arrangements in bed rooms of the class for which they are proposed.

In a bedroom where there is but one outlet the most satisfac-

tory plan is usually to run a portable lamp cord from this outlet to a portable wall bracket. Such portable wall brackets can be

FIG. 229.—Portable bracket over dresser.

hung on ornamental brass hooks at any points they are wanted, and when supplied from a central ceiling outlet can be changed at a moments notice from one part of the room to another.

Such a bracket is shown in Fig. 229, used as a dresser lamp, hung directly over the center of the mirror. It is equipped with a prismatic glass reflector, such as shown in Fig. 31, which throws a powerful light down on to the head of a person standing in front of the dresser, hence this arrangement is excellent for hair dressing, and in fact, almost all purposes for which a dresser lamp is needed except shaving. It can be made to provide the proper light for shaving in a manner mentioned later.

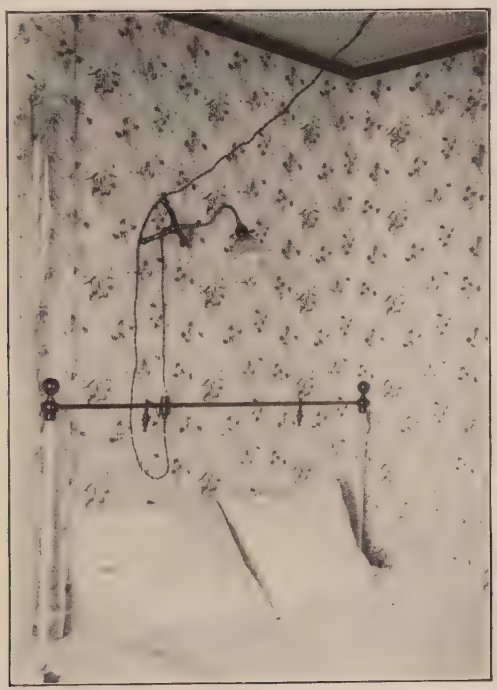


FIG. 230.—Portable bracket as reading light over bed.

Fig. 230 shows the use of the portable wall bracket as a reading lamp over the head of a bed. In this case the key socket at the attachment plug is within easy reach for turning on the light in the night. With the bracket in this position and a concentrating type of prismatic glass reflector, a four candle power lamp is sufficient for reading purposes if the bracket is to be used for that purpose alone.

If the ceiling of the room is of light color, this particular kind of bracket can be used to give a fairly good, evenly diffused light over the entire room by simply turning it up as shown in Fig. 231. By means of a thumb screw the arm of the

FIG. 231.—Portable bracket for general lighting of room.

bracket can be loosened and turned around at any angle. It can also be extended several inches to adapt it to different requirements. By turning the lamp towards the ceiling, the ceiling acts as a reflector to light the whole room by diffuse re-

flection and the light is soft and pleasing without being intense at any one point.

Fig. 232 shows how this bracket can be made to serve for shaving by setting it on the dresser in front of the mirror so as to throw the light into the mirror. The reflected light from the mirror falls on the face.

Where a portable fixture of this kind is used in a bedroom for furnishing most of the light and the owner does not wish to pay for more than one outlet, a good arrangement is to place a three or four lamp wireless cluster at the ceiling in the center of the

FIG. 232.—Portable bracket for shaving.

room. Attachment plugs for various other lighting and heating devices can then be inserted later in this wireless cluster or a lamp on a drop cord in the center of the room can be secured by attachment in a similar manner. Of course these are in the nature of makeshifts, but, as said before, bedroom, lighting especially in houses already wired, is very much of a compromise between what is desirable and what is feasible.

Fig. 233 shows an arrangement of lamps mounted directly on a dresser. On a dresser especially designed with reference to having electric lamps mounted upon it, the arrangement could

be made very artistic. On the dresser shown, there are two wall sockets mounted on each end of a piece of standard hardwood moulding fastened against the back of the mirror. The unsightly ends of the moulding are covered with round blocks of wood such as are used in mounting wall sockets, and the sockets are mounted on these blocks, the wood being finished to correspond with the dresser. The flexible cord and attach-

FIG. 233.—Dresser with lights upon it.

ment plug which connect with the wires in the moulding make it easy to connect up these dresser lamps to any socket outlet in the room. Such an outlet can either be located along the wall or at the middle of the room. In the latter case a long lamp cord is necessary. This arrangement has the advantage of always having the lamps on the dresser wherever the dresser may be moved. The lamps as shown are excellent for shaving

purposes, but must be supplemented by some higher lamp for hair dressing, as these lamps are too low to illuminate the top of the head.

A diffusing and directing globe giving a distribution similar to Fig. 80 is placed on these side lamps for two reasons: In the first place, these lamps are so nearly in the ordinary line of vision that they would have a decided blinding effect if they were not provided with something to diffuse and reduce the intensity of the light. As far as diffusion is concerned, the same results could be secured to a less degree by the use of frosted bulb lamps or by sand blasted enclosing globes. The second reason for using these globes in this place was that, in addition to diffusing the light, they direct the rays. The type of globe used as seen from Fig.80, gives such a distribution of light that when placed as these lamps are on the side of the dresser mirror, much more light will be thrown on the face of a person standing in front of the mirror than with any of the other diffusing globes mentioned. The arrangements shown in Figs. 229 and 233, combined make an almost ideal dresser lighting arrangement because it furnishes light all around the face and on top of the head.

We now come to the class of bedrooms where cost does not prevent the placing of a number of permanent fixtures.

Fig. 234 is a good example of the way bracket lamps are frequently placed in a small bedroom without any regards to the needs of the occupants and at places where they are most inconvenient. In this case the architect appears to have placed the outlets symmetrically one on each side of the windows without considering anything else. Neither bracket is where it is needed. It is impossible to make such lighting arrangements satisfactory in a bedroom. It would have been much better to have placed these two brackets on one side of the room at such a distance apart that a dresser could have been placed between them. The lamps should be frosted if used without globes or else should be covered by diffusing globes.

For large bedrooms where expense does not prevent, the arrangement of dresser lamps shown in Fig. 235 is desirable. This dresser has a lamp at each side as well as one directly over the middle of the mirror. This is the ideal arrangement as far as the location of the fixtures is concerned, although there is some room for criticism as to the shades used on the brackets

each side of the dresser. With brackets in such positions, where open shades of any kind are used, the lamps should have frosted bulbs or be enclosed in diffusing globes. As regards the lamp on the pendant directly over the dresser, it would be well, (if the neck of the globe was large enough; four inches or more), to put inside the ornamental globe some small reflector which would be concealed by the globe but which would assist greatly in throwing the light down on the head of the person using the dresser. As said before, this is a case where expense is of secondary importance, otherwise a different equipment both

FIG. 234.—Inconveniently placed bracket lamps.

of the center chandelier and of the pendant over the dresser might be advisable. The ornamental opal globes on the center chandelier absorb a large amount of light and do not distribute it very well in downward directions where it is most needed. They diffuse the light well, however, and so are good from every standpoint except that of low cost of operation for a given amount of light.

As the arrangement shown in Fig. 235 calls for more fixtures and outlets than many builders care to pay for, plans calling for fewer outlets will be discussed.

The question is, which of the three outlets around the dresser

can be most easily dispensed with. The compromise usually adopted is to omit the bracket or pendant over the mirror and have the side brackets only. If this is done the lamps on the brackets should be placed from five feet, six inches to five feet, nine inches, above the floor. This will be neither high enough to light the top of the head of a tall woman or under the chin of a short man but will answer the requirements of most persons of average height. Part of the light for the top of the head can

FIG. 235.—Bedroom fixtures properly located.

be obtained from a lamp near the ceiling in the center of the room.

Another way in which the provision of three outlets for the lighting of the dresser mirrors can be obviated is by placing one bracket lamp directly over the mirror, and if the room is to be used by gentlemen who wish to shave, providing a portable, electrically lighted shaving mirror with frosted bulb lamps mounted on each side of it. Such mirrors can be purchased ready made in the open market or made to order to suit the

purchaser. They are provided with attachment plug and cord for attachment to any socket and can be hung anywhere in a bedroom. The same plan can be used if there are brackets placed each side of the dresser but too high for shaving.

Where but a single bracket lamp is provided over the dresser mirror, it may be located too high to be reached with comfort.

FIG. 236.—Hotel Astor bedroom.

In fact, in a new house it should be located high to provide for the possibility of dressers with high mirrors being placed under it. For this reason a chain pull socket should be used on the bracket unless it is to be controlled by a wall switch.

Fig. 236 shows one of the bedrooms in Hotel Astor, New York. Here the dresser is lighted by two pendant 16-candle power lamps placed on a bracket above the mirror. These lamps are

equipped with prismatic reflectors of a concentrating type and throw a very powerful light down on the person standing in front of the dresser and some light is reflected from the cloth on the dresser to the chin so that shaving is possible, though not altogether easy because of the shadow under the chin which is relatively much darker than the face. The scheme is hardly practicable where less than two 16 candle power lamps are used, as that amount is needed to secure sufficient reflected light from the white cloth on the dresser to light under the chin. With lamps on each side of a mirror, lamps as low as four candle power can be used with excellent results. In Fig. 236 the general lighting of the bedroom is beautifully accomplished by three 16 candle power lamps at the ceiling with prismatic reflectors similiar to that shown in Fig. 32. These lamps have frosted bulbs and the room is well illuminated to its farthest corners so that reading can be done in any place in the room, although the light is much the strongest under the chandelier. The number and candle power of lamps in this bedroom is larger than would usually be demanded in a private house, since in a hotel of this class, it is necessary to provide ample light to suit the most exacting rather than to attempt economy. The chandelier arrangement, shown in Fig. 236, would not be satisfactory for general lighting without good reflectors on the lamps, and in fact, was not satisfactory before efficient reflectors were used for throwing the light down where it was needed. The light distribution of the bell formerly used was shown in Fig. 92.

Fig. 237, shows a peculiar lighting arrangement in one of the bedrooms at the Claypool Hotel, Indianapolis. The arrangement is remarkably unsatisfactory and inefficient. At the far end of the room is a two light fixture suspended from the wall outlet. This in itself, is bad for mechanical reasons, as it is likely to sag. The fixture is of very little use where it is placed, as it is almost over a radiator, so that it cannot be used to advantage either for the dresser or for reading. The two lamps used on this fixture might have been placed to much better advantage on each side of the space now occupied by the picture in which case the dresser should have been between them. The three-lamp chandelier in the middle of the room, in order to give the best general illumination in the room, should be higher and equipped with reflectors. The chandeliers in this room have

roughed white shades, which are excellent for diffusing the light but they do not cover the filaments and they let entirely too

FIG. 237.—Claypool Hotel bed room.

much light escape upwards. The room is not well lighted in all parts, even though the number of lamps is sufficient to more than accomplish this. It will be instructive to compare this

room with that shown in Fig. 236, as the same amount of power is used in both cases and the room shown in Fig. 236 is for practical purposes much better lighted.

Fig. 238 shows one of the bedrooms in the Brown Palace Hotel, Denver. Although it is not perhaps apparent from the photograph, the room is very long and narrow. The chandelier is equipped with corrugated, glass, bell shades, which act to some extent as prismatic reflectors, although very inefficient ones. The notable mistake made in this case is that the lamps are pointed cross ways of a long narrow room, so that the maximum light

FIG. 238.—Brown Palace Hotel bed room.

is thrown on the side walls opposite the chandelier, leaving the ends of the room in comparative darkness. This is a common mistake, as there seems to be some sort of a tradition among architects and electric wiremen that a two lamp chandelier should be pointed crosswise instead of lengthwise of a room or hall. If the lamps were bare and not equipped with reflectors this would be the best arrangement, but when reflectors are used, lamps should be pointed lengthwise of a room or hall. In this bedroom no provision is made for dresser lighting so that the dresser must be moved into the middle of the room if the user thereof is not to stand in his own shadow.

Fig. 239 shows an ordinary bedroom with a three-lamp chandelier, a side bracket next to the dresser and a bracket with a mantle burner in the corner. This seems to be a well lighted room. The chandelier gives good general illumination and the bracket next to the dresser is placed at the proper height to throw light on the person standing in front of the mirror. It would hardly be advisable to use a mantle burner on this bracket unless a dense diffusing globe were used. Another bracket should have been placed on the other side of the dresser. The mantle burner in the corner which is used for reading,

FIG. 239.—Gas lighted bed room.

is well placed and well equipped, except that a bobesche might be used to good advantage. This is not necessary, however, in case the person sits with his back to the lamp, or the lamp is directly above the table as in this instance.

KITCHEN LIGHTING.

The kitchen requires the best general illumination of any room in the house. In most of the rooms in the house a concentrated light at one or two places in a room is sufficient for ordinary uses. In the kitchen there is usually a sink, a table,

and a stove, upon all of which work is done, which requires good illumination. It is too frequently the case that the kitchen is the last room in the house to be considered in planning the illumination. If the dishes are to be clean and the food served free from dirt, there must be light enough in the kitchen to show the condition of dishes and food. A poor light will cover up a multitude of defects in dishwashing and general cleanliness.

FIG. 240.—Common faulty kitchen lighting.

Fig 240 shows a common faulty method of kitchen lighting, which consists simply of hanging a bare lamp on a drop cord about six feet from the floor. Now, from Fig. 16 it is seen that a bare lamp will give an unnecessary amount of light to the side walls and ceiling and not enough down on the stove, sink and table with such an arrangement. Further, from

what has gone before, it is evident that a bare lamp like this, hung in the middle of the kitchen, has a certain blinding effect on persons attempting to see across the room, and hence detracts from the efficiency of the illumination. Further than this it is objectionable because, with table, stove, and sink located around the sides of the room, the users must always stand in their own light or else stand very much to one side.

FIG. 241.—Good position for kitchen light.

Where a single lamp must serve for the lighting of the whole kitchen, the best plan is to put it at the ceiling in the center as in Fig. 241, with a reflector which will throw light over all of the lower part of the room. A reflector giving the maximum light at an angle of about 40 to 50 degrees below the horizontal is the one to choose for such a location, in a kitchen 10 feet square

or less. Reflectors shown in Figs. 19 and 37, come in this class. In a larger kitchen this maximum light should be 35 to 40 degrees below the horizontal as in Figs. 23 and 27.

Another better arrangement for kitchen lighting than a single central ceiling light would be to place bracket or pendant lamps well up over the sink, the table, and the stove, using them with downwardly pointed sockets and reflectors of opal or prismatic glass. With three four candle power bracket lamps of this kind the power consumption will be about the same as with one 16-candle power lamp and by concentrating light on the three points where the most work is done will give a better light for working, although the general illumination of the room will not be as good. It sometimes happens that cupboard doors and windows interfere with such bracket arrangement in kitchens. A bracket lamp over a stove will require frequent cleaning on account of the steam and grease rising from the cooking. For this reason a Holophane globe should never be used in such places; either an opal or prismatic reflector with a smooth inside surface being preferable.

In a small pantry the best thing that can be selected is a lamp in the middle in a diffusing globe hung about six feet from the floor, because what is needed here mainly is good light on the shelves. In a large or butler's pantry, the conditions are similar to those in the kitchen and a reflector to direct the light down should be used.

Porch Lighting.

The requirements for porch lighting are evidently to light the floor of the porch and the steps to it as well as to throw light on a person standing on the porch. This means, of course, a strong downward light. The ordinary incandescent lamp as was seen in Fig. 16, throws less than one-half its rated candle power directly downward so that if this type of lamp is to be used, some means should be adopted to increase the downward light. For artistic reasons a closed form of globe is usually chosen, as in Fig. 242, instead of a reflector, although a reflector is by far the most economical thing that can be used. If a good prismatic reflector is employed, a four candle power lamp is usually sufficient, although an eight candle power lamp is better. Another plan sometimes adopted is to use a turn-down lamp having the one candle-power filament turned on

for the ordinary everyday requirements of lighting the porch and steps and using the 16-candle power filament on special occasions. Some favor the use of an opal or ground glass ball on a porch because the house number can be painted on the ball. This is of little value because there is, or should be, a number on or near the door readable from the street by day-

FIG. 242.—Inefficient porch light.

light. This number can be read by night if the lighting of the porch is what it should be. The number that can be placed on any ordinary size of opal globe is too small to be read from the street.

One of the best forms of porch lighting is by hemispheres placed on the ceiling, as in Fig. 243. A single lamp should be mounted

inside in the center pointing straight downward and provided with a reflector inside of the hemisphere as recommended in the chapter on clusters and bowls. When used with a reflector almost any kind of diffusing hemisphere can be used, ground glass being preferable to opal and opaline because of its higher efficiency and more artistic appearance. If the lamp cannot be pointed down a Holophane hemisphere will assist greatly in directing the light down as shown in Fig. 159. An effective

FIG. 243.—Good plan for long porch.

and practical arrangement for porch lighting when using hemispheres, where expense is of secondary consideration is to place one lamp in the center for common use and others surrounding it and controlled by a separate switch.

When a ball effect is desired, one should avoid the typical example shown in Fig. 242 where most of the light is thrown sideways and on the ceiling and the minimum downward where it is wanted. By the use of a ground glass ball with a four inch holder permitting the use of an 8 or 16 candle power lamp with

a small prismatic reflector hanging directly on the lamp inside the globe, a pleasing and efficient arrangement can be obtained. It is also possible to use in such cases a prismatic reflecting ball as shown in Fig. 88 or globes of the kind shown in Figs. 78 and 82. It is not possible to obtain as great efficiency using an

FIG. 244.—Good bath room mirror lighting.

enclosing globe even with a reflector inside of it as can be obtained with a lamp in a large reflector without the enclosing globe.

Brackets are often effectively and artistically employed in porch lighting. Such cases present practically the same problems as ordinary bracket lighting which has been treated.

Fig. 243 shows a good plan for lighting a large porch. One hemisphere with a lamp and reflector inside of it is placed at the end of the porch most frequently used and another hemisphere for occasional use at the other end of the porch, controlled by a separate switch. If only one lamp is placed on a long porch where the steps and the door are at one end, it is usually better to put the lamp over the end most commonly used or at the front door rather than in the middle.

Bath Room Lighting.

The lighting of the bathroom depends somewhat on the amount of use that is to be made of the bath room mirror. In a small bathroom where the mirror is not used much, a lamp in the center on a pendant about 6.5 feet above the floor, and equipped with a reflector which gives good general distribution below the horizontal, will answer very well. A preferable arrangement is to place it at the ceiling and control it with a wall switch. A lamp of four or eight candle-power is usually sufficient. Where mirror lighting is important, the arrangement shown in Fig. 244 is good. In this figure, the upright lamps on brackets on each side of the mirror are equipped with Class B Holophane globes, which diffuse the light and also direct most of it below the horizontal. Because of the fact that bath rooms have usually light walls and ceilings, reflectors do not play as important a part here as in dark colored rooms, although, in the example given in Fig. 244 there is so much dark wood work in the vicinity of the brackets that the per cent of reflection is very low.

Hall Lighting.

The lighting of a long hall in a residence from one fixture can best be accomplished by placing a two-lamp fixture with lamps near the ceiling at the middle, placing frosted tip lamps in concentrating reflectors and pointing them so that the maximum intensity of light is in the direction of the floor at the ends of the hall as in Fig. 245. This accomplishes the lighting with one outlet. For longer halls two or more outlets are advisable. In the latter case the lamps may be placed on pendants either in diffusing globes or in reflectors giving a general distribution of light below the horizontal, such as Figs. 21, 23 and 80.

The use of a turn-down lamp in a hall is frequently desirable in which case the cords for turning up and down must be within reach of an ordinary adult from the floor, or a wall switch can be provided. The use of side brackets for wall lighting is also artistic and permissible. Lamps in side brackets should be always frosted or enclosed in diffusing globes. The main thing in hall lighting is a general moderate illumination without concentration at any one point, and without any blinding glare from bare lamps placed in the ordinary line of vision.

Basement Lighting.

In the basement in the average residence but a limited amount of light is needed at night, but what few lamps there are must illuminate a large area. It is best not to provide anything which will collect an unnoticed amount of dirt, and for this reason flat, opal reflectors and lamps, placed near the ceiling, usually make

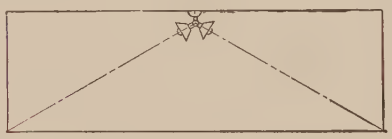


Fig. 245.—Diagram of hall lighting.

the best combination. If a more concentrated light is wanted than is afforded by a flat, opal reflector, some conical reflector can be used. Where several lamps are used in a basement they may all be connected to one switch at the top of the basement stairs and all sockets may be equipped with a " turn-down " lamp, which has one filament of one candle power, and another filament of 16 candle power. The one candle power filaments will be kept turned on, so that they will light whenever the switch controling the basement is thrown on. After the switch is thrown on, the user has a dim light from the one candle power filament with which to find his way around, and whenever he desires more light at one lamp, can immediately turn on the 16 candle power filament. When he leaves the basement all lights are turned off at the one switch. It is well to provide in most basements a length of portable cord and an extension plug for temporary light in dark corners.

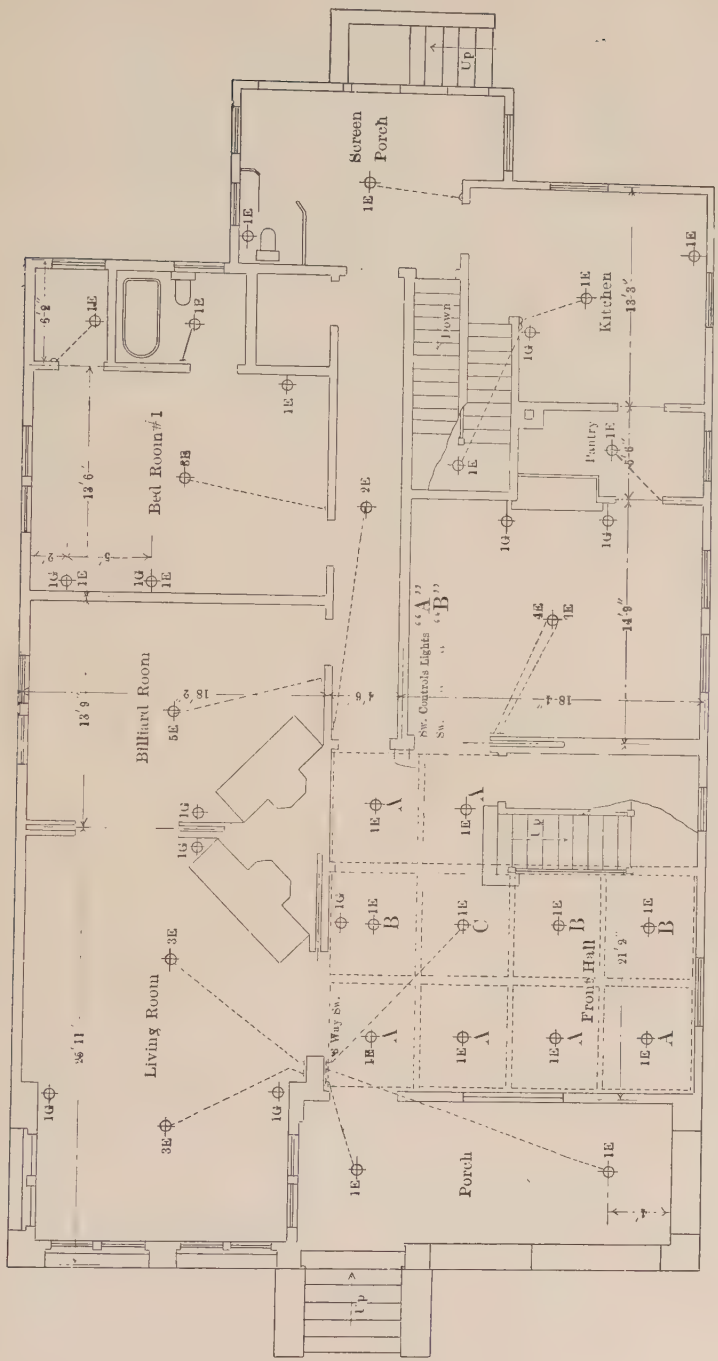


FIG. 246.—Plan of first floor.

Room or Location	No of Outlets	No of Fixtures	No of Lights Gas	No of Lights Electric	No of Lights per Outlet	Height of Outlet	Height of Socket	Style of Socket	Kind of Switch	Style of Fixture: Sketch No	Style of Fixture: Catalog No	Catalog No of Glassware	Diameter Holders	Lamps: No	Lamps: C.P.	Remarks
Basement																
foot stairs	1			1		ceiling	ceiling	keyless	1 snap			28	2½"	1	16	switch at top of stairs
furnace room	1	1	1			5'								1	5'	
furnace room	1			1		ceiling	6'6"	pull		drop cord		28	2½"	1	16	provide 10' extension cord and plug
front room	1			1		ceiling	6'6"	pull		drop cord		28	2½"	1	16	
large room	2			2		ceiling	5'	key		drop cord		28	2½"	2	16	provide cord adjuster
First floor																
front porch	2	2		1		ceiling	ceiling	keyless	2 push fl.×	4		89	3½"	2	8	Separate circuits
front hall	10	10		1		ceiling	ceiling	keyless	4 push fl.	4		79	3½"	10	4	on 3 switches one on 3 way at upper and lower halls
front hall	1	1	1			5'6"							3 bare candle	1	10'	
hall closet	1	1		1		5'6"		key		6				1	4	
living room	2	2		3		ceiling	6'9"	pull	1 push fl.×	7		89	3½"	6	16	On separate switches
living room	3	3	1			5'6"							3 bare candle	3	5'	
billiard room	1	1	1			5'6"							3 bare candle	1	5'	*this billiard table glassware is like fig 38 only deeper
billiard room	1	1		5		ceiling	7'	key	1 push fl.	5	*		2½"	5	16	
bed room No1	1	1		3		ceiling		key	1 push fl	7		32	1⅛"	3	8	
bed room No1	1	1		1		6'		pull		2		32	1⅛"	1	4	18" chain on socket
bed room No1	2	2	1	1		5'6"		key		1				2	8	frosted lamps
hall	1	1		2		ceiling	8'	keyless	1 push fl.	9*		32	1⅛"	2	8	*point sockets lengthwise of hall
screen porch	1			1		ceiling	ceiling	keyless	1 snap			20	2½"	1	8	
screen closet	1	1		1		5'6"		key		6				1	4	
center kitchen	1			1		ceiling	ceiling	keyless	1 snap			22	2½"	1	16	
kitchen sink	1	1		1		ceiling	6'6"	pull		8		20	2½"	1	8	
kitchen range	1	1				5'6"								1	5'	*round frosted lamps *goes inside ar glass dome *dome and ceiling sep circuits
pantry	1	1		1		ceiling	6'6"	pull		8		95	2½"	½	8	
dining room	1	1		5		ceiling	6'	keyless	2 push fl.	3		38*		½	8	
dining room	2	2	1			5'6"							3 bare candle	1	5'	
bed room No1-closet	1	1		1		7'6"		keyless	1 snap	2		20	2½"	1	4	30" instead of 20
bed room No1-bath	1			1		ceiling	8'	keyless	1 push fl.	8		32	1⅛"	1	4	
Second floor																
bed room No 2	1	1		3		ceiling	8'	key	1 push fl.	7		32	1⅛"	3	8	
bed room No2	1	1		1		5'6"		pull		2		32	1⅛"	1	4	
bed room No 2	2	2	1	1		5'6"		key		1				2	8	
bed room No 2-closet	1	1		1		7'6"		keyless	1 snap	2		20	2½"	1	4	30" instead of 20"
bed room No 3	1	1		3		ceiling	8'	key	push fl.	7		32	1⅛"	3	8	
bed room No 3	1	1		1		5'6"		pull		2		32	1⅛"	1	4	
bed room No 3	2	2	1	1		5'6"		key		1				2	8	
bed room No 3-closet	1	1		1		7'6"		keyless	snap	2		20	2½"	1	4	30" instead of 20"
bed room No 4	1	1		3		ceiling	8'	key	push fl.	7		32	1⅛"	3	8	
bed room No 4	1	1		1		5'6"		pull		2		32	1⅛"	1	4	
bed room No 4	2	2	1	1		5'6"		key		1				2	8	
bed room No 4-closet	1	1		1		7'6"		keyless	snap	2		20	2½"	1	4	30" instead of 20
bed room No 5	1	1		3		ceiling	8'	key	push fl.	7		32	1⅛"	3	8	
bed room No 5	1	1		1		6'3"		pull		2		32	1⅛"	1	4	18" chain
bed room No 5	2	2	1	1		5'6"		key		1				2	8	
bed room No 5-closet	1	1		1		7'6"		keyless	snap	2		20	2½"	1	4	30" instead of 20
bed room No 6	1	1		3		ceiling	8'	keyless	push fl.	7		32	1⅛"	3	8	
bed room No 6	1	1		1		5'6"		pull		2		32	1⅛"	1	4	
bed room No 6	2	2	1	1		5'6"		key		1				2	8	
bed room No 6-closet	1	1		1		7'6"		keyless		2		20	2½"	1	4	30" instead of 20"
servants' room	1	1		2		ceiling	8'	key	snap	7		32	2½"	2	8	
servants' room	1	1		1		5'6"		pull		2		32	1⅛"	1	4	
servants' room	2	2	1	1		5'6"		key		1				2	8	
servants' closet	1	1		1		ceiling	7'	keyless	snap	8		20	2½"	1	4	
servants' bath	1	1		1		ceiling	8'	keyless	snap	8		32	1⅛"	1	4	
servants' bath	1	1	1			5'6"								1	5'	
main bath	1	1		1		ceiling	8'	keyless	push fl.	8		32	1⅛"	1	4	
main bath	1	1	1			5'6"								1	5'	
front end hall	1	1		2		ceiling	8'	keyless	push fl.	9		32	1⅛"	2	8	point sockets lengthwise of hall
rear end hall	1	1		1		ceiling	8'	keyless	push fl.	8		85	2½"	1	4	
Attic																
ceiling	1			1		ceiling	8'	keyless	snap			28		1	32	extension plug and cord with portable lamp
between windows	1			1		3'	3'	key wall					wire guard			

An Example of House Lighting Design.

In order to illustrate further the principles which have been set forth and to offer some suggestions as to the rapid carrying out of the work of drawing up lighting specifications the authors have selected for presentation the design of the lighting for a specific house where the planning of the illumination could be treated with a free hand from the beginning. The planning of the illumination for a house or any building should precede that of planning the wiring, because illumination is the ultimate purpose for which the wiring is to be installed. As illumination is the primary object desired, we should work back from the desired illumination to the outlets, installation of wires and machinery and not vice versa, as is too frequently done.

The accompanying plans shown here in Figs. 246, 247 and 248 are of a house where the owner desired to obtain excellent illumination with a minimum operating cost. It was recognized at the outset that the first cost of installing the lighting system was small when compared with the running or operating cost from year to year and therefore an effort was made to reduce operating expenses by securing a maximum efficiency of illumination rather than to cut down the cost of installation in general.

The most rapid and convenient method of drawing up lighting specifications that the authors have found is to mark on the architect's floor plans the location of the outlets or fixtures and at the same time draw up a schedule like the one here shown. Such a schedule can be made out very rapidly compared with any other method of specifying the necessary items with regard to each outlet or fixture. It is a quicker and easier job for the contractor and workmen to get information off such a schedule than from ordinary specifications. On the schedule a separate item is made for each outlet except where there are a number of similar outlets and fixtures in a room. The plans show the location of the fixtures and switches together with the sketches of fixtures. The plans taken with table or schedule furnish nearly all the information necessary for the contractor so that as regards this part of the work but few other specifications are necessary. It should be noted on the accompanying schedule that in the case of all wall brackets the height of the outlet is in every instance specified and in the case of lamps suspended from the ceiling the height of the socket from the floor is given. From such a sche-

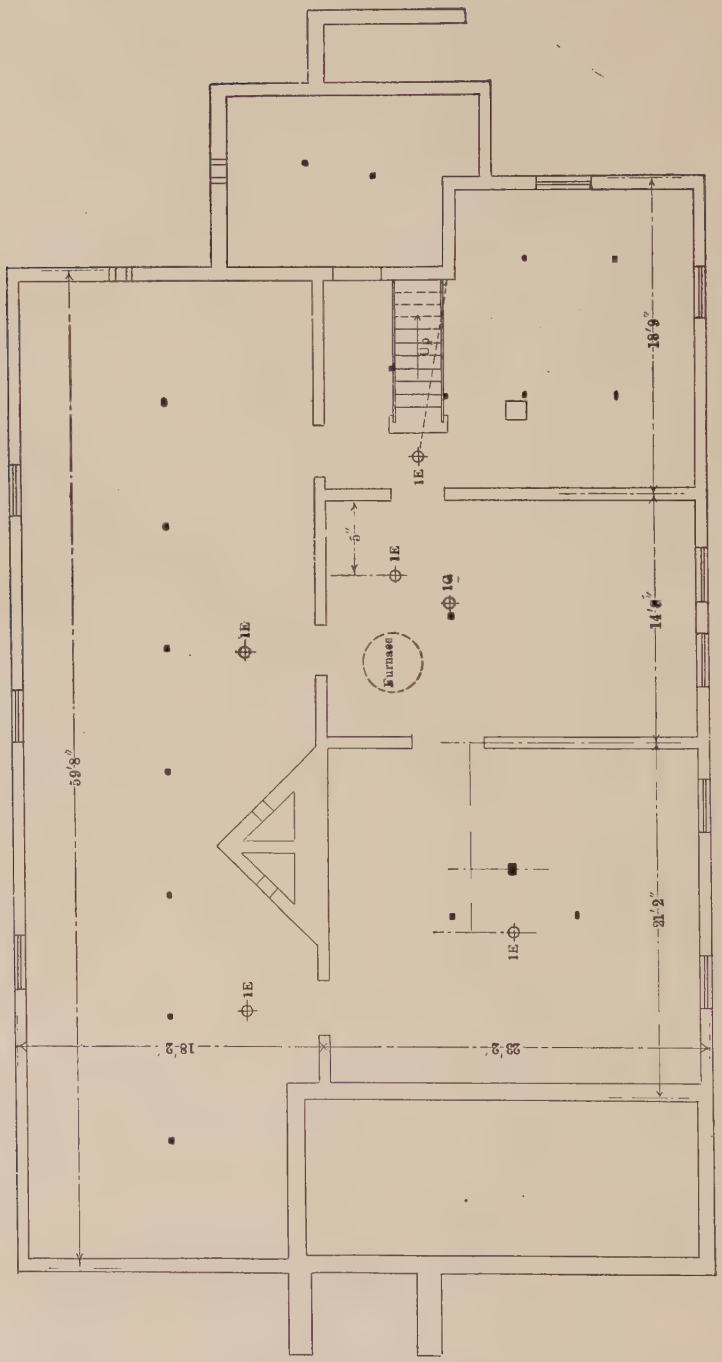


FIG. 247.—Plan of cellar.

dule, together with a plan showing the location of lamps, the wireman can immediately take off all that is necessary for his use and the fixture man has complete specifications except as to the particular design of fixture for each case.

The sketches for the chandeliers and brackets as noted in one column on the schedule and as given in Figs. 249 and 250 (sketches 1 to 9), are rough, free-hand drawings intended only for the purpose of indicating at what angle the lamps should hang and indicating only in general the style of fixture; the selection of fixtures being left entirely to owner and fixture dealer with the sketches for guides. Should the fixtures be definitely selected from a fixture dealer's catalogue when the schedule is being made out the dealer's catalogue number should be used instead of the sketch number, as the trouble of making the sketches is thus avoided.

The specifications for the wiring are outside the province of this book.

In planning the location of fixtures, especially that of wall brackets in bedrooms, it is desirable to have some means of quickly showing the probable location of furniture or of trying the furniture in different locations. For doing this either in conference with the owner of the house or even if the entire matter is left to the illuminating engineer, a plan adopted by Mr. J. Kermode of the Cleveland Electric Illuminating Company, is to be recommended. Blocks of wood representing furniture and made to the same scale as the architect's plans, (0.25 inches representing one foot), are provided so that beds, dressers, chairs and tables can be arranged in the room under consideration just as they would probably be after the house is finished. In this way both the engineer and the owner can see what is wanted much more quickly than by attempting to picture the situation mentally and measure up the available spaces with a rule.

The location of fixtures is marked on the plans, Figs. 246 to 248, by the usual cross and circle. 1 *E* marked opposite a fixture on the plans indicates one electric socket, 2 *E*, two electric sockets, and so on. Gas tips are indicated by the mark 1 *G* opposite the fixture. Switches are indicated by dotted lines leading to the lamps they control whenever feasible.

In the schedule it will be seen that one column is devoted to the Fig. number (in this book) of the glassware to be used on

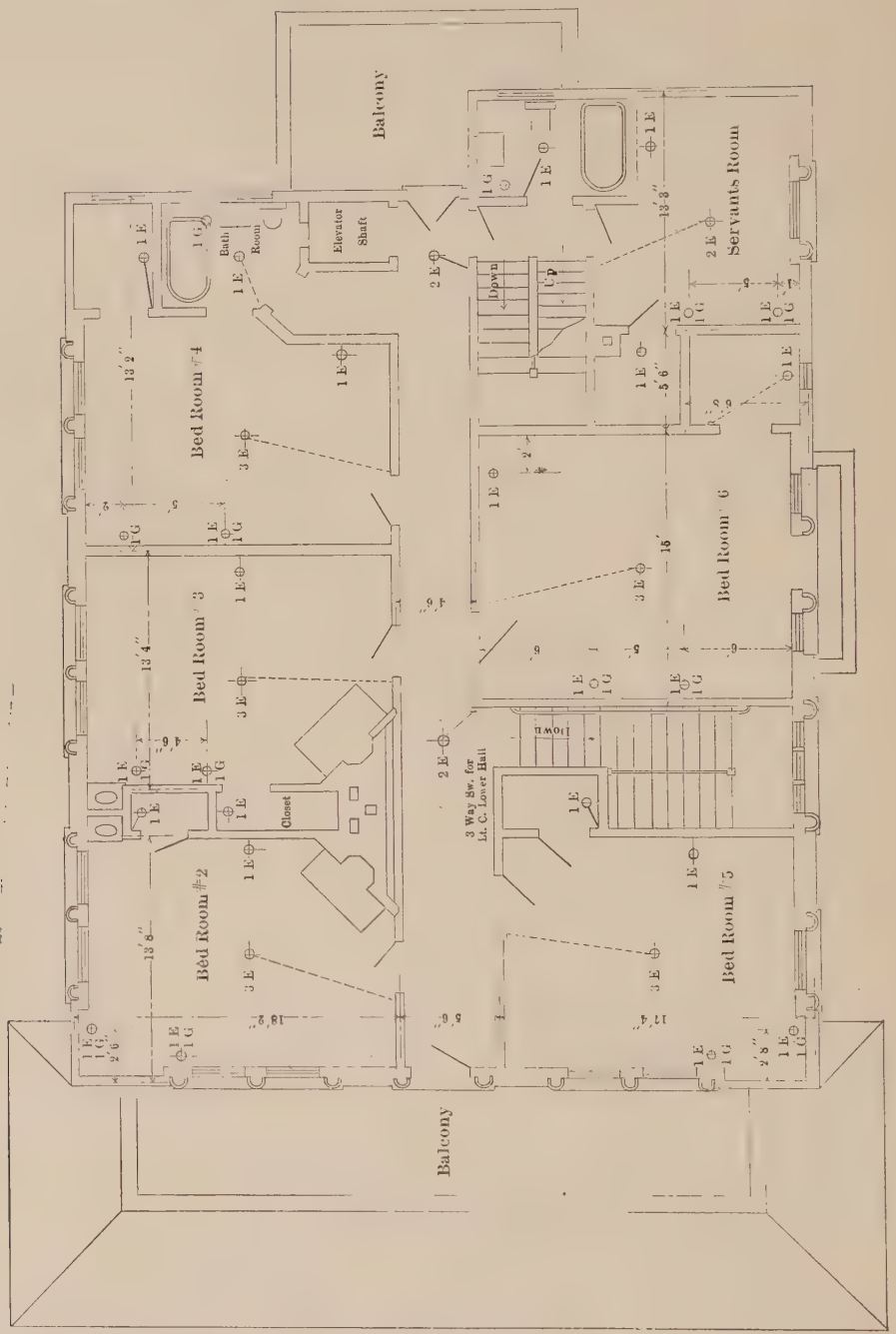


FIG. 248.—Plan of second floor.

each fixture. In practice this column should be used to give the manufacturer's or supply dealer's catalogue number of the shade or globe required. If glassware from more than one dealer or

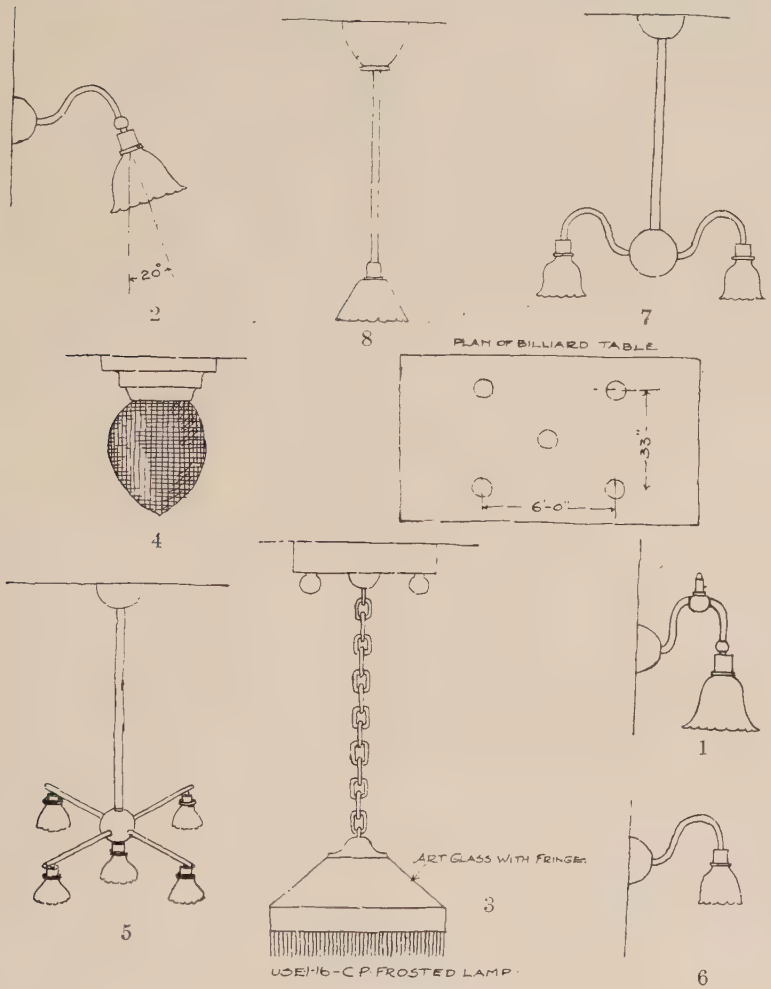


FIG. 249.—Sketches 1 to 8.

manufacturer is needed the numbers can be followed with stars, and other reference marks, referring to the catalogue or maker's names in foot notes at the bottom of the sheet. Such foot notes would then read:

* Catalogue of X. Y. Z. Supply Co.

** Catalogue of A. B. C. Glass Co., etc.

It is manifestly not necessary to make out the whole schedule at once. Parts can be left blank and filled in later. In some cases part of the columns will not need to be used.

Where much work is being done it is a good plan to have blank schedules printed on tough, thin bond paper. When once the original blank is filled out, blue prints can be obtained of it for bidders, contractors and workmen, or carbon copies can be made if pencil is used. If not enough work is being done to justify this and duplicate copies of the schedule are not needed, a blank schedule with column heads lettered in can be drawn on a piece of tracing cloth. Blue prints can be made of this and the schedule filled out in red pencil on the blue print. For small jobs in small towns this will answer.

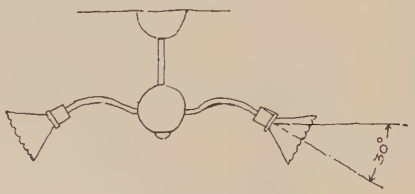


FIG. 250.—Sketch 9.

Although electric lighting is depended upon almost entirely in this house, a few gas jets have been provided for use should the electric service be temporarily interrupted.

The reason for adopting the plans as shown can best be seen by considering each room briefly. These remarks, however, simply supplement and further explain the plans and schedule. The essence of the specifications is contained in the plans and schedule and each item on the schedule should be studied before reading the following supplementary explanations about the various rooms.

Porch.—One lamp was placed in front of the door to illuminate the doorway and steps. Inasmuch as the porch would probably be used in the evening another lamp was desirable and placed at the other end. These lamps are controlled by separate switches so that only one need be turned on. A ball globe with directing prisms, like Fig. 89, was specified because of its handsome

appearance and its ability to throw the light strongly downward although reflectors would have given a greater amount of downward light. In case it is desired to read on the porch, 16-candle power lamps are necessary, otherwise eight or four candle power lamps will suffice.

Front Hall.—The lamps in the front hall or reception room were placed on three separate circuits. One lamp which can be used as a night lamp is controlled both from a three way switch placed close to the entrance and by another three way switch upstairs. Lamps *A* were placed on another switch and lamps *B* on a third switch. With these three switches it is therefore possible to get a number of combinations of light and the arrangement is such as not to interfere with the symmetry and artistic effect of the lighting when they are not all turned on. These lamps have globes which are calculated to deliver the light down in the room.

Living Room.—As this room was large, two chandeliers were used, equipped with cut glass prismatic reflecting balls hanging straight down so as to throw the maximum light on a table or on the book of a person sitting underneath.

Billiard Room.—In order to provide first, uniform table illumination of sufficient strength; second, to avoid shadows which are unavoidable when the light is concentrated over the middle of the table; third, to keep the light as much as possible out of the eyes of the players to prevent blinding; fourth, to provide sufficient general illumination in the room to make it possible to count the string easily and, fifth, to keep the glassware out of the way where it would not be easily broken, the arrangement of the five lamps over the table as indicated in sketch No. 5, was decided upon; the dimensions on the sketch being those found by experience in billiard rooms to give satisfaction. The bed of a billiard table is generally 31 inches above the floor and if the bottom of the shades are about four feet above the bed of the table the results will be satisfactory. Generally speaking, the lamps when using the shades specified (giving an even distribution of illumination over an area 45 degrees each way from the vertical) should be for a 5 x 10 foot table 6.5 feet apart lengthwise and three feet apart sidewise. For a 4.5 x 9 foot table they should be six feet lengthwise and 33 inches sidewise. In both cases the sockets should hang six feet seven inches from the floor

which would bring the reflector about four feet from the bed of the table.

Bed Room.—The bed rooms were all treated practically alike. The general illumination is given by a three lamp chandelier placed in the center of the ceiling, eight feet above the floor. The lamps are pointed downward and provided with a rather concentrating form of reflector with eight candle power lamps, which give a good light throughout the room and provide ample concentrated illumination for writing and reading directly underneath. With very dark walls this candle power might have to be increased somewhat. With light colored walls it is ample. A bracket is provided on each side of the dresser, the brackets being placed five feet apart and equipped with bare frosted bulb lamps, the natural distribution of light about which is such as to throw the maximum light on a person standing in front of the mirror. If gas had not been necessary on the same fixture, it would have been better to place the electric lamp upright on these brackets. With the form of center chandelier used (which is close to the ceiling), sufficient light is thrown on the top of a person's head to light the hair and make unnecessary a bracket or pendant lamp over the top of the dresser. With less light from the central chandelier or with the chandelier lower, a lamp over the dresser mirror would be necessary. Over the head of the bed is provided a four candle power lamp in a concentrating reflector with a chain socket to provide for reading in bed and easy access to one awakening in the night. Gas is provided in each room simply for use in case of breakdown of the electric service.

Kitchen.—One lamp was placed in the center of the ceiling of the kitchen for the general lighting of the room. The reflector chosen, lights evenly the entire lower portion of the room. A lamp was placed on a bracket over the sink to give a strong light where most needed in dish washing.

These notes, in connection with the plans and sketches will enable the reader to make a study of the methods and reasons for arrangements adopted.

CHAPTER XVII.

DESK, DRAFTING ROOM AND OFFICE LIGHTING.

In the lighting of desks there are five principal requirements:

1. The lamp should be out of the line of ordinary vision of the person working at the desk or should be shaded so that the rays cannot strike the eye.

2. The position of the lamp with reference to the top of the desk should be such that the worker at the desk will not receive the regular reflection or glare from paper on the desk. This regular reflection is one of the commonest causes of trouble in continued working at an artificially lighted desk.

3. The light should be free from streaks or striations .

4. Too great intensity of light should be avoided. An intensity of from two to five foot candles (normal) on the top of the desk is about right.

5. The light should be steady—in other words, the lamp should not be swinging; and if it is electric light the voltage regulation must be good.

A very common and popular method of lighting desks is by the use of a cylindrical desk shade at the center of the desk, as in Fig. 251. While this arrangement is fairly satisfactory, it is capable of much improvement. The lamp is in such a position that when the user of the desk attempts to read or write with a paper directly in the middle of the desk in front of him, there is so much reflection or glare from the paper as to make it not only very trying to the eyes, but difficult and sometimes impossible to read. The work must usually be shifted either to one side or the other of the desk or the lamp must be shifted. The cylindrical desk shade shown in Fig. 251 does not throw a light nearly as strong as the parabolic aluminum reflector shown later in Figs. 256 and 257, as can be seen from the light distribution of these reflectors given in Figs. 58 and 60.

Fig. 252 shows one of the most satisfactory, comfortable and efficient ways of desk lighting. Here the lamp is located on the

bracket at the left hand end of the desk. The bracket is equipped with a concentrating type of prismatic glass reflector giving a light distribution similar to Fig. 31. The user of a desk so lighted experiences practically no discomfort from the glare or regular reflection from the paper, while at the same time the desk is well lighted over its entire surface. The comfort of working at such a desk as compared with those lighted by many of the common methods is remarkable. The lamp is high enough above the user of the desk to be out of the line of ordinary vision and further-

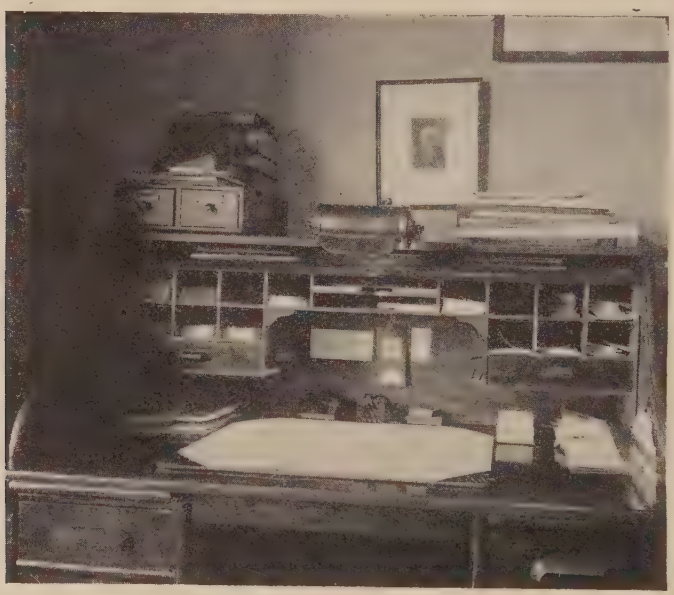


FIG. 251.—Poor arrangement of desk lamp.

more the eyebrows shield the eyes with the head in ordinary working position. It is not absolutely necessary to equip the lamp with a frosted bulb for diffusing purposes. It is advisable so to equip it, however, on account of other occupants of the room, and because the light is so well diffused by the frosting that less glare is received from the work on the desk and it is consequently an easier light to work by. The lamp should be so placed that a plumb line dropped from the lamp to the top of the desk would strike about one foot from the front edge of the desk. This is important if the best results are to be obtained.

The bracket in Fig. 252 would give good results with any one of several other types of concentrating reflectors, such as shown in Figs. 19, 21, 51, 53, and 56. The two first should always be used with frosted bulb lamps, and in fact frosting is desirable for any desk lamp for the reasons before explained.

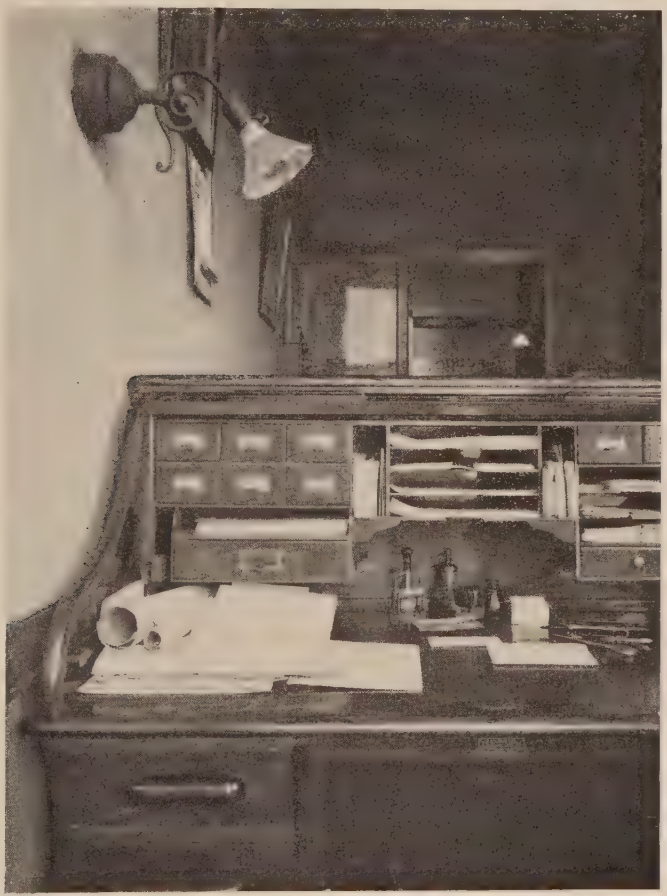


FIG. 252.—Desk lamp in right position.

The same relative location of the lamp shown in Fig. 252, can be obtained with portable desk lamps, as, for example, in Fig. 253 which shows a fixture of special design. This fixture, however, does not bring the lamp as far out toward the front edge of the desk as it should to give the best results. It should overhang

far enough to bring it directly above a point one foot from the front edge of the desk, as before explained.

Fig. 254 shows the same position of the lamp as in Fig. 252, but with an ordinary portable desk fixture equipped with a green opal desk shade. A large opal shade like this, however, is too heavy for the ordinary desk portable if placed in the position giving the best results. An aluminum cone such as shown in Fig. 52 would be much lighter and better illuminate the desk. A prismatic reflector like that shown in Fig. 32, would also be light

FIG. 253.—Desk portable in fair position.

enough to be safe. It will always be necessary to eliminate the streaks which accompany the light from the opal desk shade by using a frosted bulb lamp.

Fig. 255 shows a misdirected attempt to light a desk which is bad from every standpoint. A powerful prismatic reflector mounted on a bracket above the middle of the desk throws the light down at such an angle that the occupant gets a large amount of glare from the paper by working anywhere near the middle of the desk, and receives the full glare of the light from the reflector

whenever he raises his eyes. Furthermore, much of the light does not fall on the desk, but on the person who is using it. This could be easily rectified by simply turning the desk around as shown in Fig. 252.

Fig. 256 shows an excellent desk fixture misused. Here the desk is small, and in placing the lamp in the parabolic aluminum reflector in the position shown it is entirely too close to the paper. The intense light is concentrated on the paper at one point, the edges of the desk being in darkness, and there is much glare or reflection from the paper under the reflector so that the only

FIG. 254.—Position for standard portable desk lamp.

portion of the desk which is well lighted can hardly be used without ruining the eyes. On a low top desk such as this, the proper position for such a fixture is as shown in Fig. 257. Here the lamp is virtually placed in the same relative position to the user as in Figs. 252 and 254. The fixture is a very useful one because it can be adjusted in so many different positions. The parabolic aluminum frosted finish reflector with which it is equipped (see Figs. 58 and 60), is more efficient than the cylindrical desk shade shown in Fig. 251.

Fig. 258 shows the proper position for a lamp on a flat-top

FIG. 255.—Bad position for desk lamp.

FIG. 256.—Good desk portable misused.

desk or table. The stand should be placed near the left-hand elbow and an opaque shade should be used, pointed at such an angle that the light will fall on the work without striking the eyes of the user. This position can manifestly be obtained with several other types of portable desk lamps. Fig. 258 was taken merely to show the proper position.

Fig. 259 shows a method by which as a makeshift, a lamp on an ordinary drop cord can be made to give a fairly satisfactory desk illumination. The lamp should hang over the left-hand end

FIG. 257.—Desk portable properly adjusted.

of the desk. By looping a short piece of cord around the thumb-screw on the shade holder and tying the other end around the lamp cord, as indicated, the lamp can be given the proper angle to light the entire surface of the desk.

With opaque desk shades other light should always be used in the room to supplement the desk light, as otherwise there will be too much strain on the eye in changing frequently from the brightly lighted top of the desk to the dark room. With opal or prismatic glass reflectors enough light escapes through the reflector

FIG. 258.—Proper position for lamp on flat top desk.

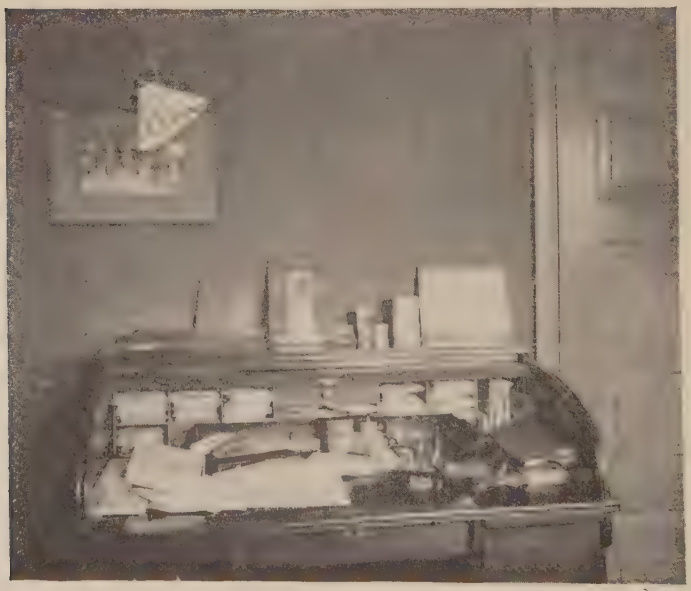


FIG. 259.—Good desk illumination by a makeshift.

for considerable general lighting of the room, so that other lighting of the room may not be necessary.

Fig. 260 has been selected as a splendid example of how not to do it. Almost all the principles of good illumination have been violated in this case. In the first place, the lamps are so placed, that when a man looks up from his work, he will have the bare gas mantle glaring him directly in the eye. Second, the light from the lamps will strike the paper at such an angle that it will be regularly reflected, with a resultant glare which will soon produce

FIG. 260.—Badly lighted tables.

injurious results. Third, the light is not diffused and the intensity is therefore too high. Fourth, sufficient amount of light is not thrown on the work and there are annoying shadows. In fact, this furnishes a very good example for a gas man to show his customers how not to light their desks. It would be well in this case to use an opal dome and bobesche which would render the light soft to the eye and give far more light on the work than the present equipment.

Fig. 261 shows an office where as far as the lighting arrangement is concerned, cheapness is evidently the primary object. The

lamps are placed in such a position that when working at the desk one either sits in his own shadow or else as the light comes from the right, one has a constant shadow of the hand. In fact the arrangement is about as poor as could be conceived.

The same general principles that apply to the lighting of desks apply to the lighting of drafting tables with some modifications. On a drafting table much higher intensity is required and an illumination of ten foot-candles is none too much, since the light must be sufficient to shine through heavy tracing cloth on to pencil

FIG. 261.—Absurd office lighting.

drawings underneath. The proper position for a drafting table lamp is at the left of the worker near the far left-hand corner of the table. As it is necessary to place the lamp in front of the worker in order to avoid shadows from the rulers the only way to keep the light from shining in the eyes is for the draftsman to wear a shade over his eyes. A powerful reflector should be used on the lamp and it should be pointed usually toward the near right hand corner of the board. A frosted lamp should always be used over a drafting table and for ordinary large tables a 32-candle power

lamp will be required. The object of the frosted lamp is of course to avoid streaks and to reduce the glare from the paper.

What has been said heretofore in this chapter as to the lighting of desks has been intended to apply to cases where the general illumination of a room is not sufficient to give all the light that is wanted on the desks and special desk lamps are required. This is a condition which exists in a great majority of offices and drafting rooms. There is another method which is that of providing

FIG. 262.—Drafting room lighting with vapor lamps.

a great abundance of light in all parts of the room, and so making individual desk lamps unnecessary. Attempts made to provide enough illumination by means of arc lamps as ordinarily equipped so that individual desk lamps are not needed, are likely to be unsatisfactory because of the sharp shadows and the fact that many of the workers at the desk are likely to be in such position as to cast shadows on their own work. With the mecury vapor lamp, where the light comes from a long tube and with ordinary arcs in very large reflectors or concentric diffusers, however, light

usually comes from sufficiently large surfaces so that, if the walls and ceilings are light in color, shadows do not give trouble, even though the light from only one or two lamps falls on a desk. These large lighting units are manifestly suited only to large offices. It must be remembered that this scheme of providing for desk or drafting table lighting with the same lamps that are used for the general illumination of a large room is only applicable when a great abundance of light is provided. In many offices such an abundance of light in all parts is a good investment because of the higher working efficiency of the employes it secures. It is especially desirable where there are long book keepers' desks and numerous filing cabinets to light because the numerous low lamps necessary to light these by special or individual lighting would be difficult to arrange so that they would give a good light for the purpose intended and at the same time not shine directly in the eyes of a number of workers.

With mercury vapor lamps, office lighting of the character indicated can be accomplished with an expenditure of from 0.5 to one watt per square foot of surface to be lighted, depending on the color of the walls. With arc lamps it can be accomplished with from 1.2 to 2.5 watts per square foot. For drafting room lighting with mercury vapor lamps from 1 to 2 watts per square foot should be allowed and with arc lamps from 2.5 to 5 watts per square foot.

Fig. 262 is the drafting room of the Link Belt Engineering Company at Nicetown, Pa. The drafting tables are arranged so that light from the windows comes from the front and left of the draftsmen during the day, consequently the mercury vapor lamps are placed so as to have the light come as nearly as possible from the same direction at night. This is a rule that should be followed in all drafting room lighting.

CHAPTER XVIII.

THE LIGHTING OF PUBLIC HALLS AND LODGE ROOMS.

In the lighting of public halls, lodge rooms and the like, the object to be obtained is an even, general illumination of the whole room with as little eye-trying glare in the eyes of the audience as possible. In audience rooms of all kinds, it is desirable either to conceal the sources of light, or, if this is not practicable to place them high, and so far out of the ordinary line of vision that the effect on the eye will be least detrimental. The rays from a source of artificial light, if that source is not very intense, may not be sufficient to cause noticeable discomfort to a person with strong eyes. When one sits for a long time with the rays

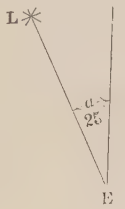


FIG. 263.—Critical angle for eyebrow shading.

falling in the eye, however, there usually follows a slight unpleasant burning sensation, the cause of which the owner is frequently not aware of. The only way to obviate this entirely is to keep the sources of light where direct rays from them cannot fall in the eye. Some discomfort will result from light coming from above and in front of a person sitting as in an audience unless the light is arranged so that the eyebrows shade the eyes from all direct sources of light. This practically means that light should not be placed where it can shine directly on the face of a person in the audience unless it shines at an angle of less than 25 degrees in front of a perpendicular drawn through the eye. The eyebrows

will usually cut off all rays of light coming at less than 25 degrees from such a perpendicular. Thus in Fig. 263 if the eye is at E and the source of light at L, the angle a, should be 25 degrees or less for the most comfortable lighting. Wherever possible the lamps should be placed so that no rays shine backwards at an angle of over 25 degrees from the vertical. As such placing is frequently not practicable, the use of diffusing globes is the next best thing, always keeping the lamp as far out of the ordinary line of vision as possible.

Fig. 264 is an example of a well-lighted lodge hall. The lamps

FIG. 264.—Well lighted lodge hall.

are placed high on the ceiling and are enclosed in globes such as shown in Fig. 79 which diffuse the light and at the same time give the maximum amount of light downward. A prismatic reflecting ball like Fig. 89 would produce similar results. It would have been possible to have lighted this hall well by using instead of these globes, a prismatic reflector with frosted bulb lamps. The latter arrangement would probably have resulted in a higher intensity of light on the floor, since reflectors give a stronger downward candle power than the globes mentioned. The general effect would have been more trying on the eyes on account of the less perfect diffusion of the light, and the cost of

lamp renewals would have been greater since frosted bulb lamps have only approximately half the life of clear bulb lamps enclosed in globes. The hall shown in Fig. 264, which is a lodge room known as Washington Hall in Chicago, is 44 feet wide by 50 feet long. There are 48 lamps of 16 candle power on the two ceiling beams and 11 lamps in the circle at the center. The six lamps back of the platform should hardly be counted as aiding in the useful illumination of the room, as they detract from rather than add to the general effect, and should never be turned on. Counting the ceiling lamps only, therefore, there are 59 16-candle power lamps to illuminate this hall of 2,200 square feet floor

FIG. 265.—A bad method of hall lighting.

space. With lamps taking 56 watts each the power consumption would be 1.5 watts per square foot of floor space in this room. The illumination is good except when the lamps get blackened with age and need renewing.

Fig. 265 shows an assembly room lighted mainly from a central chandelier. This chandelier is equipped with opal bell reflectors. The light falls in the eyes of persons seated in the back rows. Although a central chandelier is the common method of lighting such a room, it is hard on the eyes of that part of the audience which must face it. It would have been better to place the lamps at the rear and sides of the room so that the rays

would not fall in the eyes of persons in the audience. Somewhat higher efficiency could be secured with the present chandelier and reflectors by pointing the lamps straight down, because with this reflector, which, as seen from Fig. 23, gives a wide distribution of light, an unnecessary amount of light is thrown toward the ceiling when the light is placed at an angle as in this case. A better way if the chandelier is retained would be to raise the chandelier near to the ceiling and use powerful prismatic concentrating reflectors to throw the light down, leaving the lamps at about the same angle as shown, thus getting the lamps more out

FIG. 266.—System of lighting ruinous to eyes.

of the line of vision. The bracket lamps on either side of the stage are very trying since they must be faced by the audience.

Fig. 266, the Masonic Temple lodge room in Chicago, is a glaring example of how not to light such a room. The large number of bare lamps placed on the arches make it impossible for persons in the audience not to receive a large amount of light from these lamps directly in the eyes. Furthermore, since there are no reflectors on the lamps, a large amount of light is wasted which could be directed downward were reflectors used. The lighting of this hall could be considerably improved by simply putting on deep reflectors with frosted bulb lamps, which would increase

the amount of illumination on the floor and decrease the glare. In planning the lighting of a new room of this kind the lamps should be placed behind rather than upon the arches and thus be hidden from the view of the audience when the room is used for general entertainment purposes. If this were done, the lamps should be placed at an angle of about 45 degrees to the ceiling, pointing forward toward the platform, and equipped with efficient reflectors to direct the light forward and downward. If possible, no light should be allowed to shine backward toward the audience at an angle of over 25 degrees from perpendicular for reasons explained at the beginning of the chapter. The question of concealing lamps in audience rooms is taken up further in the chapters on church lighting and theater lighting.

CHAPTER XIX.

THE LIGHTING OF LARGE DINING AND BANQUET ROOMS.

In the lighting of banquet rooms custom has dictated that the effect must be that of brilliancy and a flood of light. The same has been to a large extent demanded in large dining rooms and is still demanded in the majority of cases, although for certain rooms, (such as grill rooms and rathskellers), in many high-class hotels and restaurants recently, a subdued effect is aimed at.

FIG. 267.—Dining room of Auditorium Annex, Chicago.

Fig. 267 shows a dining room of the Auditorium Annex Chicago lighted with large chandeliers having clusters of frosted bulb lamps. Brackets equipped with frosted bulb lamps bring up the illumination along the sides of the room. The effect is that of brilliancy and plenty of light without glare. This is a case where reflectors, although they would increase the efficiency,

could not be used for artistic reasons. Such cases, however, are rare. In a dining room of this kind expense of operation is an entirely secondary consideration.

Fig. 268 shows St. Huberts Grill room, Chicago, which is both efficiently and artistically lighted by means of lamps equipped with Holophane spheres. These spheres not only diffuse and soften the light, but direct the rays downward so as to secure good efficiency. These spheres should have been hung nearer the side walls to produce the best distribution of light but since that would not have looked well, side brackets were put in to bring up the illumination along the side walls.

Fig. 268.—St. Huberts Grill, Chicago.

Fig. 269 is of the Auditorium banquet room, Chicago, an excellent example of an arrangement which is ruinous to the eyes. The lamps are located on certain architectural features of the room suspended from the ceiling. No one seated in the room save those near the ends can fail to get an immense amount of glare from the array of lamps in clear bulbs. Even the use of frosted bulbs which should be insisted on in a case of this kind would hardly render this arrangement tolerable to a person not having strong eyes. To sit an evening through facing these lamps is a very uncomfortable experience and undoubtedly adds much to

FIG. 269.—Auditorium banquet room, Chicago.

FIG. 270.—Dining room in Auditorium, Chicago.

the profits of Chicago occulists. The effect of such light falling in the eyes for long periods of time, as before explained, is to produce discomfort either in the way of smarting, burning sensations, or headaches. The average person with strong eyes does not notice these things until too late.

Fig. 270 shows the lighting of a dining and banquet room in the Auditorium Hotel, Chicago, which is almost, though not

FIG. 271.—Wasteful lighting of restaurant.

quite as bad as the main banquet room shown in Fig. 269. Lighting is done by means of bare lamps placed on the arches. The use of deep reflectors on these lamps would considerably increase the efficiency and reduce the glare that proves so ruinous to the eyes of those who must face it continuously. Frosted bulbs should by all means be used. The effect of opal or prismatic reflectors would be to deliver a large percentage of useful light down on the tables and reduce the amount of light shining in the eyes of

persons looking lengthways of the room. This would materially improve the conditions. The lamps low down on the arches are objectionable in any event as they are inevitably in the ordinary line of vision of some of the people seated at the tables. This room is occasionally used as an assembly room; in which case the same objections as to the present lighting would hold. If used exclusively as an assembly room with the platform at the far end the lamps should all be concealed behind the arches so as to be out of sight of the audience.

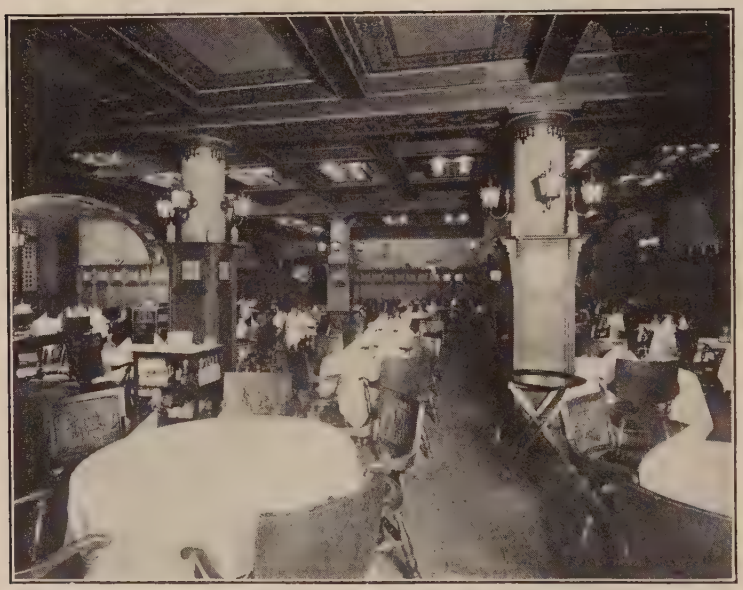


FIG. 272.—German room Hotel Stratford, Chicago.

Fig. 271 is an excellent example of how not to light a restaurant. The ceiling is dark. It is studded with incandescent lamps over which there are no reflectors. The candle power of lamps in this room is ample to light the tables fairly well and yet the lighting is far from satisfactory, owing simply to the darkness of the ceiling and the absence of reflectors.

Fig. 272 which is of the German room of the Hotel Stratford, Chicago, is an example of the class of lighting before referred to, in which a subdued effect rather than great brilliancy is desired.

The principal lighting is done by lamps placed in special box light fixtures against the ceiling. These boxes have art glass bottoms and open sides. A more absurd design both from an artistic and illuminating standpoint would be hard to imagine. The open sides permit the glaring lamps to appear in all their crudity while the dense art glass bottoms absorb most of the light going down. Such a box fixture should have a ground glass bottom and art glass sides and should be deep enough to permit the lamps to be pointed straight down. The lamps should be equipped with opal or prismatic reflectors to throw the light down through the

FIG. 273.—Glare and waste in restaurant lighting.

ground glass. Such a box fixture would be excellent both in efficiency and protection of the eyes. The tables would be well lighted and at the same time the subdued effect desired in such a room would be secured by the comparative darkness of the ceilings and walls.

Fig. 273 shows the lighting of a large restaurant where the chandeliers are placed low and equipped with opal bell reflectors such as shown in Fig. 24. Chandeliers equipped with reflectors of this kind should have the lamp sockets pointed straight down, otherwise too much light is thrown toward the ceiling. Frosted

bulb lamps should be substituted for clear bulb lamps in this case, because of the large amount of lamp filament exposed. With these two changes, the lighting of this room would be efficiently done.

Fig. 274 shows the lighting of the dining room in the Chicago Atheletic Club in which bare lamps are placed on ceiling stalactites. These lamps should be frosted. The lighting arrangement of this room is fairly satisfactory, except to persons who are suffering from overstrained eyes to whom presence of light which cannot be avoided is objectionable. However, since the ceilings are high, it is easy to avoid the rays from the lamps near

FIG. 274.—Dining room of Chicago Athletic Club.

by. From an illuminating standpoint it would be better if the form of the ceiling were reversed, that is, if the lamps instead of being placed on the tips of stalactites were placed in recesses in the ceilings so as to be invisible except to those under them.

Fig. 275 shows a restaurant lighted with lamps placed in ornamental stalactite globes. The efficiency of this lighting could be much increased by the substitution either of good reflectors for the stalactite globes or by the use of Holophane stalactites which would direct the light downward. The present stalactites act only to absorb the light without directing it, so that a large percentage is wasted in the upper portions of the

FIG. 275. Crude effect with opaline stalactites.

FIG. 276.—Efficient ceiling lighting.

room and in the globes themselves. The effect is also crude because the lamp filaments show through the opaline globes.

Fig. 276 is a view of a dining room in the Windermere Hotel, Chicago, with somewhat similar placing of lamps to that shown in Fig. 275 but in which the efficiency is much greater by virtue of the use of Holophane globes and hemispheres for directing the light downwards as well as for diffusing it.

Fig. 277 shows the Cafe Martin, New York. Here the principal lighting is done from ceiling fixtures equipped with prismatic reflectors which deliver a large amount of light down on the tables.

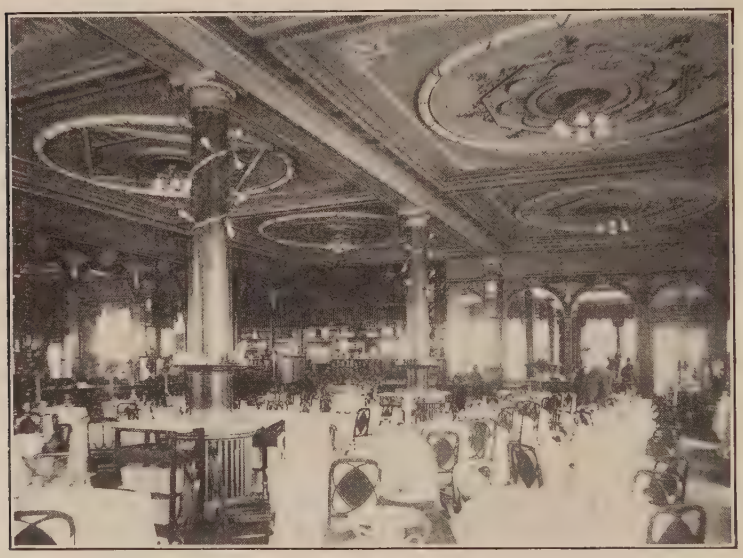


FIG. 277.—Cafe Martin, New York.

These fixtures are high enough to be well out of the ordinary line of vision of persons seated at the tables. Reflectors extending over the lamps also tend to reduce the glare received by persons seated some distance away. The decorative lighting is accomplished by frosted bulb lamps placed on vines on the pillars. It is worthy of note that with a high ceiling of this kind until reflectors such as shown in Fig. 32 were used, very much higher candle-power lamps were necessary. The reflectors not only increase the economy but make a more subdued effect possible, and render the illumination easier on the eyes of the users.

CHAPTER XX.

THE LIGHTING OF LARGE PUBLIC ROOMS, DEPOTS, LOBBIES, ETC.

In the lighting of hotel lobbies, large railroad depots, main floor halls of large buildings, etc., the object to be attained is a general cheerful effect, good illumination on the floor and absence of glare. Glare in such places invariably looks crude and cheap. Its only legitimate use is in cheap advertising by electric light. The day has passed when it is to be tolerated in high-class buildings. The object should be to produce a brightly lighted and cheerful effect without bringing the sources of light into glaring prominence.

Fig. 278 which shows the interior of the Union Depot at Indianapolis, is an example of lighting in a style common a few years ago, but seldom installed now. The principal lighting is by enormous and elaborate chandeliers hung high from the middle of the arch. The position of the lamps is very good, and they are high enough to be inoffensive to persons in the waiting room below. With lamps placed high, it is important that more care be given to equipping them with efficient opal or prismatic glass reflectors than was given in this case. The lamps on the chandelier are equipped with etched glass bell shades which are of little worth in directing the light downward. The location of the bracket lamps along the edge of the balcony floor is excellent and would be very efficient were efficient translucent glass reflectors used to throw the light down in the waiting room. The tendency of late for railroad depots and places of this kind has been away from elaborate chandeliers with a large number of small incandescent lamps, and toward fewer and larger lighting units and these on simple but substantial fixtures, or toward lamps placed directly on the ceiling.

Fig. 279 shows the interior of the Union Depot at Pittsburg, which is lighted in an unusual but very effective manner by means of six-glower Nernst lamps hung in the space between the first

and second skylights. The result is an excellent diffused light coming through the skylight, giving the same effect as when the room is lighted by daylight. The room is about 150 feet long, 65 feet wide and 40 feet high. There are 105 six-glower lamps hung 4.5 feet above the skylight. The skylight is wired clear

FIG. 278.—Indianapolis Union Depot.

glass, with a ribbed surface, and is from $\frac{1}{4}$ to $\frac{3}{8}$ in. thick. The absorption of the glass is about 25 per cent. Clear glass globes and white enameled metal reflectors 14 inches in diameter by 4 inches high are used over the lamps. The use of concentrating reflectors on the lamps is necessary owing to the height of the lamps above the floor 45 feet below.

The effect of the lighting is, on the whole, extremely good, and one can easily read anywhere, a desirable quality in a waiting room. It is probable that four instead of six-glower lamps could be used here and the illuminaton still be sufficient, although the

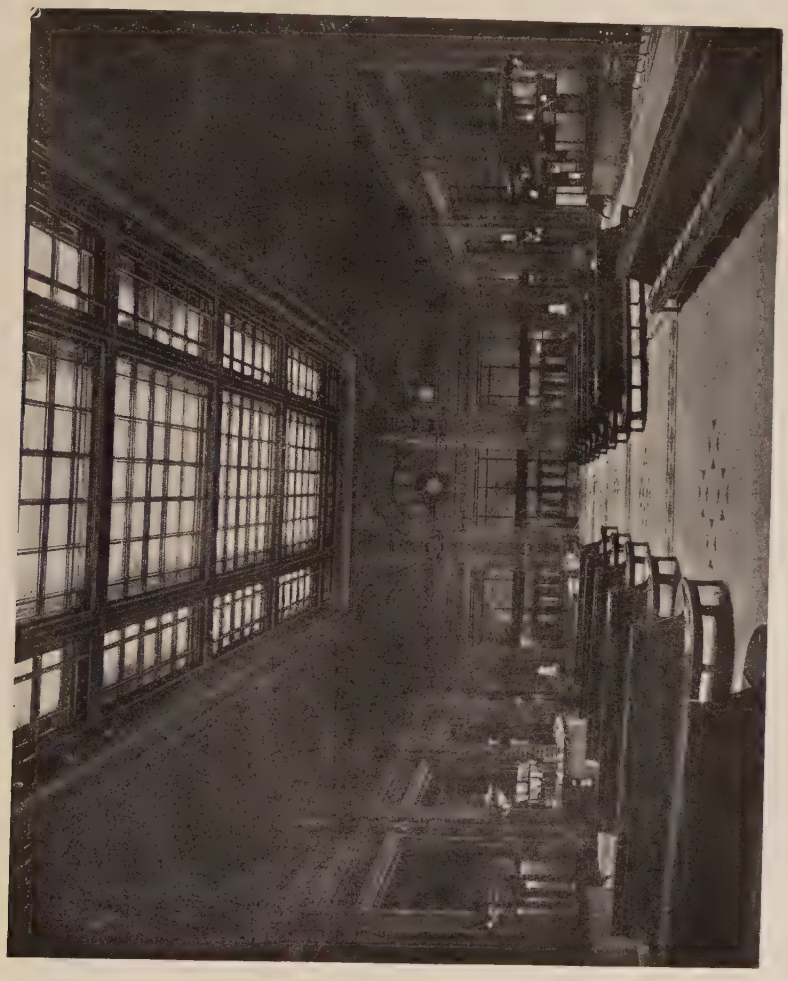


FIG. 279.—Pittsburg Union Depot.

present effect of brilliancy might be lost. As the skylight does not extend over the entire room, there is some little difference in the illumination between the sides and the center, but not enough to be greatly objectionable, as the illumination is sufficient

at all points for the purpose for which the room is intended. The chief objection is from the artistic standpoint, as the skylight is badly streaked, due to the kind of glass used in the skylight itself.

Fig. 280 shows the lobby of the Majestic Hotel in Chicago. Here handsome modern fixtures are equipped with Holophane globes with a hemisphere in the center. These globes which are similar to that shown in Fig. 83, give excellent diffusion of light. The illumination downward from the hemisphere could be much increased by the use of reflectors over the lamps, as shown in the chapter on clusters and bowls.

FIG. 280.—Majestic Lobby, Chicago.

Fig. 281 shows the lobby of the Auditorium Hotel Chicago, as originally equipped. The lighting is done by ceiling clusters below small mirror reflectors of an inverted cone shape. These reflectors not only look crude, cheap, and out of keeping in such a location but are too small and not of the proper size or shape to be very efficient. For a cluster of this kind a very much larger reflector is needed. A cluster in which each individual lamp is equipped with an opal or prismatic reflector and is frosted would be much better looking and would throw much more light downward. With clusters placed as high as this and individual reflectors on each lamp, these reflectors should be of a fairly concentrating

type so as to deliver as much light as possible in the direction the lamp is pointed. With a small inverted cone reflector such as used, a large amount of light strikes the ceiling from which a part of it is reflected to the side walls and from thence to the floor.

FIG. 281.—Auditorium Lobby, Chicago.

As there is loss in each reflction, but a small percentage is delivered where it is most needed.

Fig. 282 shows the lobby of the Auditorium Annex Hotel, Chicago, as it appeared when originally equipped. The rows of bare lamps along the ceiling beams are not in accordance with

modern ideas of artistic lighting. The arrangement is certainly not efficient, since by use of glass reflectors over the lamps a part of the glare from the bare filaments could be avoided and much more light delivered down in the room. This is a case where frosted bulb lamps should be used. The lighting of this lobby has since been changed to an entirely different scheme.

Fig. 283, which was taken in the hall of the Historical Society Building, in Chicago, shows some things to be avoided in this class of lighting. The lighting is accomplished by clusters of lamps on brackets placed rather low. These lamps are in opal bell reflectors, such as shown in Fig. 24, which expose a large

FIG. 282.—Old arrangement of Annex Lobby, Chicago.

part of the lamp bulb. The result is a large amount of glare in the ordinary line of vision of persons entering the room, which detracts from the general effect of the illumination. These lamps should have been placed higher and more out of the line of vision, and should have frosted bulbs or be enclosed in diffusing globes, inasmuch as the hall only requires general illumination and not any special illumination at particular points.

Fig. 284 shows the lighting of the main hall and stairway of the Colonial Theatre, Chicago, where the lighting of the architectural details is the principal thing to be obtained. For this reason

no attempt at directing the light in special directions is necessary. The lighting is done by upright bracket fixtures equipped with ground glass globes such as shown in Fig. 75, and basket fixtures

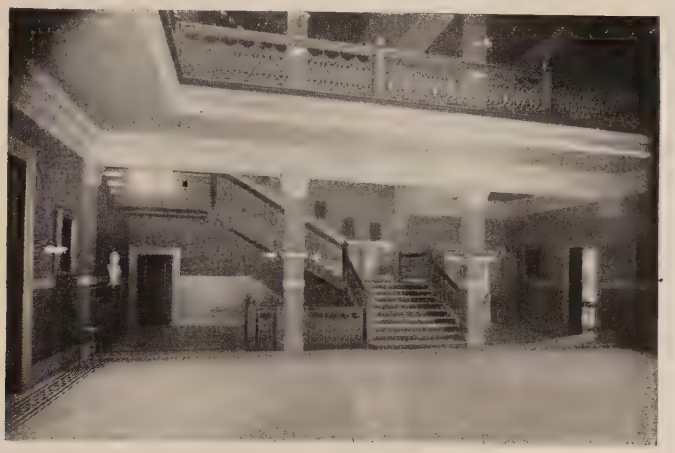


FIG. 283.—Glare in line of vision.

FIG. 284.—Entrance to Colonial Theater, Chicago.

hanging from chains. The greater part of the lighting is done by the bracket lamps. The principal thing to avoid in a location of this kind is the use of opaline globes, which do not diffuse the

light to any extent and which show the lamp filaments through the glass, these filaments having a sickly red hue and producing a general crude effect out of keeping with the surroundings. Globes selected for use in such a place should either be frosted or sand blasted, or a sufficiently dense opal so that the lamp filaments will not show through. If dense opal globes are used, the total candle power in lamps provided must be 25 per cent. more than if frosted or sand blasted globes are used. With opaline globes which allow the lamp filaments to show through, the difficulty can be partly overcome by using frosted bulb lamps but this is not advisable since the frosted lamps have about 50 per

FIG. 285.—Stratford Lobby, Chicago.

cent. of the life of clear glass lamps, and the same results with less expenditure can be accomplished by using frosted enclosing globes instead. When basket reflectors such as shown in Fig. 284 are used in such a location, it is to be remembered that they act to a certain extent as reflectors to throw the light upwards, which in the case of lighting arches and vaulted ceilings is desirable.

Fig. 285 shows the lobby of Hotel Stratford, Chicago, in which the principal lighting is accomplished by lamps located in art glass baskets hung by chains from the ceiling. This class of lighting is in order where expense is entirely secondary to artistic considerations. In baskets of this kind it is advisable to use either

turnip-shaped reflector lamps in a cluster pointing outward at an angle of about 45 degrees, or ordinary lamps equipped with some good common type of reflector which will not deteriorate with heat. The latter is preferable where there is room in the basket, because reflector lamps with a mirrored backing on the globe

FIG. 286.—Bad mixture of light in office building.

have a much shorter life than standard lamps and fall off rapidly in efficiency.

Fig. 286 shows the lighting of the lobby of a large office building in which arc lamps are hung above the main area and a border of incandescent lamps is placed around the edges. This mixture

of arc and incandescent lighting in a place like this produces a bad effect as the whiteness of the arc light tends to make the incandescent look sickly yellow. As a general principle a mixure of different kinds of illuminants in this way almost never produces a good effect. The arc lamps in this hall have since been replaced by incandescent lamps placed in large Holophane spheres hung by chains, considerably lower than the arc lamps. The incandescent lamps in Fig. 286 should be frosted. Reflectors are not necessary in this location because of the white marble surroundings. The clear bulb incandescent lamps, however, produce a crude, inartistic effect on account of their glare.

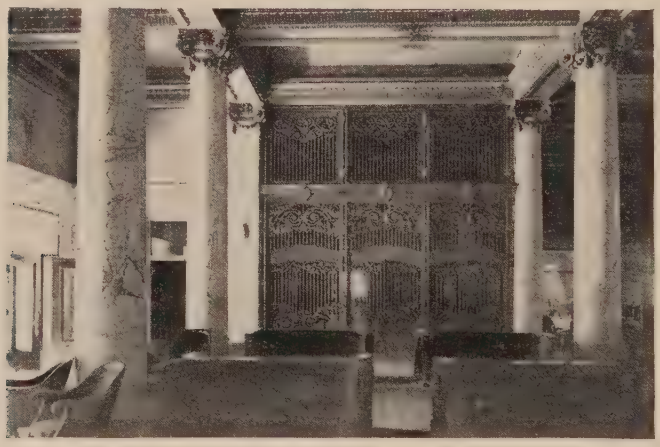


FIG. 287.—Indirect lighting in Hotel Jefferson, St. Louis.

Fig. 287 is a view in the lobby of Hotel Jefferson, St. Louis, which is an interesting example of what is usually known as indirect lighting. The lamps themselves are not visible, being placed in a cove behind beams next to the ceiling at points marked "A A". Fig. 288 shows a cross-section through one of these beams and coves. The lamps are placed in trough mirror reflectors, these reflectors being placed at such an angle that the light is thrown towards the ceiling from which it is reflected down into the room to accomplish the desired illumination. It is, of course, essential that the ceiling be light in tint. Because of the fact that all of the light must be reflected from the ceiling such a

scheme of illumination requires a greater candle power in lamps than direct illumination. With indirect illumination the light comes entirely from the ceiling. The result is an absence of shadows and also an absence of glare either from the lamps or from the objects illuminated, which makes both indirect illumination and daylight easier on the eyes than any scheme of artificial illumination where the light comes directly from intense sources of light.

In the ladies' parlor of this same hotel which is lighted the same way, there are 65 lamps of 16-candle power. The room is oval in shape, being 34 feet 8 inches long by 26 feet 6 inches wide. The area is 645 square feet. If 56-watt lamps are used, the current required would, therefore, be about 5.6 watts per square

FIG. 288.—Section of cove lighting plan.

foot as against about 2.5 which would ordinarily be ample for a room of this character with direct illumination.

Indirect illuminating arrangements are not to be recommended for locations in dirty cities as their effectiveness is so rapidly reduced by dirt darkening the ceiling and collecting in the reflecting trough under the lamps. In no case should it be used unless attention is frequently given to keeping the reflecting surface and the ceiling clean.

A modification of this indirect lighting scheme sometimes used is to have a few bracket lamps in diffusing globes so as to have a little light coming from a definite source and so avoid the almost entire absence of shadow and contrast that some object to where all the lighting is indirect.

Fig. 289 shows a lobby in which most of the lighting is done

by bracket lamps, located high on pillars. The lamps are enclosed in sand blasted globes open at the bottom. If a globe of this shape is used, as it is here, for the sole purpose of enclosing the lamp, it is better not to select one which is open at the bottom as a closed globe will look better and prevent the collection of dirt on the globe if closed with asbestos at the top. The arrangement shown is fairly good and artistic. In a lobby of this kind where the ceilings are fairly low, it would be possible to design special ceiling fixtures which would conceal the sources of light from those not sitting directly under them. Deep art glass domes or boxes with ground glass bottoms, and lamps equipped

FIG. 289.—Good lighting of a lobby.

with reflectors inside them, the reflectors being of such shape as to distribute light over the square spaces between four posts would accomplish this well. A distributing rather than a concentrating reflector should be used . The light would not be offensive to those seated under it because it would be so far out of the line of vision that the rays would not strike the eye to any great extent while to those seated in an adjoining section of the room the lights would not be visible.

Fig. 290 shows the rotunda of the Rookery Building, Chicago, recently equipped with artistic fixtures. The central spheres are Holophane glass and similar globes are placed on each of

the four corners. These globes direct the light downward, and at the same time diffuse it so as to avoid the glare.

Fig. 291 shows the lobby of Hotel Vendome, Boston. The cen-

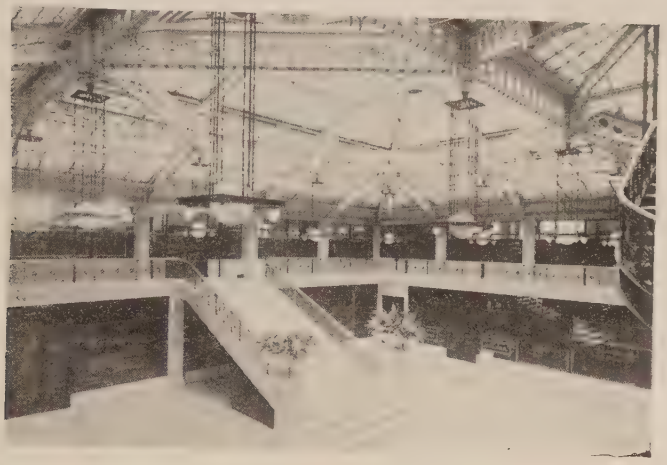


FIG. 290. Rotunda of Rookery, Chicago.

FIG. 291.—Lobby of Vendome Hotel, Boston.

tral basket of art glass is surrounded with a group of lamps in Holophane stalactite globes which accomplish most of the useful lighting. The arrangement is an excellent one in so far as it

avoids a mistake sometimes made in connection with this type of fixture, namely, that of using reflectors on the lamps outside the baskets which allow the clear glass lamp bulb to be exposed in all its crudity, thus spoiling the artistic effect of the basket. The globes used in this case increase the illumination at all angles below the horizontal.

CHAPTER XXI

THE LIGHTING OF HALL AND CORRIDORS OF LARGE OFFICE BUILDINGS.

The lighting of halls of large office buildings, hotels and public buildings is frequently one of the most difficult tasks in illumination for the reason that the artificial light must be used during the daytime when the halls are also partially lighted by daylight. The light from electric incandescent lamps which must be used as a rule in such places is likely to appear yellow and sickly by contrast with white daylight. The object to be attained in the lighting of long halls and corridors is to produce a general cheerful well lighted effect. Here is a case where the lighting of the ceilings and side walls as well as that of the floor is important. Nevertheless, the color of the floor plays a prominent part in the general effect and it is almost impossible to make a hall with a very dark floor appear well lighted. It is important to have the lamps well distributed along the length of a long hall rather than to place large lamps or clusters at less frequent intervals. The reason for this is very simple. With chandeliers or clusters at infrequent intervals, the spaces midway between clusters appear poorly lighted by contrast with those portions of the hall near the clusters. The result is that this alternation of light and dark places makes the hall appear gloomy and poorly lighted even though the total candle power of lamps may be sufficient. Therefore to light a long corridor well, it may be laid down as a first principle that small lighting units at frequent intervals should be employed. These units may be equipped in a variety of ways as explained later.

The next problem is to so equip the lighting units as to avoid the glare of a row of bare incandescent lamp filaments as one looks the length of a hall. This glare, in addition to looking crude, cheap and inartistic in the evening, has the further objection that it looks sickly and ineffective when a hall is partially

lighted by daylight. Enclosing globes of sand blasted glass or lamps with frosted bulbs have the effect of making the electric incandescent lamps appear to much better advantage when there is a mixture of daylight and artificial light besides looking the more refined and artistic at all times. Holophane globes while they accomplish the purpose of diffusing and reducing the intensity of light and at the same time redirecting its rays, do not appear to as good advantage when there is a mixture of daylight as do sand blasted or frosted globes.

In the lighting of hotel corridors off which there are sleeping rooms the problem is somewhat different from that in office and public buildings and corridors off the lobby of a hotel because the upper part of the hotel corridor must be kept dark to prevent light shining through the transoms and annoying guests who have retired for the night and wish an absolutely dark room.

Fig. 292 shows a corridor in the State Mutual Building, Boston, in which correct principles are carried out in the location of lighting pendants at frequent intervals down the length of the hall. These pendants are in this case equipped with Holophane spheres which for the reasons before mentioned are more permissible in a dark hall of this kind than in one where there is a considerable mixture of daylight. One lamp with a flat reflector as explained in Chapter VIII, is the best equipment to be placed inside of spheres in such a location. In a hall where there is much daylight an arrangement like that in Fig. 292 might be employed with the substitution of ground glass spheres in place of the Holophane spheres and the use of a flat opal or prismatic reflector over the lamp inside each sphere. With an arrangement such as shown in Fig. 292 it is possible although of questionable utility (as explained later), to equip each sphere with two lamps on separate switches so that either one or two lamps can be turned on as may be required, thus giving two different intensities of illumination in the hall. If two intensities are desired, this is a much better arrangement than that of turning off the light on every other pendant as is sometimes done. The effect of turning off every other lamp is to produce light and dark areas down the length of the hall making it appear gloomy as well as spoiling the appearance of the row of lamps.

Another way of providing for lamps on separate switches at

each outlet in corridor lighting is to install hemispheres as shown in Fig. 293.

As to whether two intensities of light are practically needed in the ordinary office building, there is room for argument, although it is to be seriously doubted whether such provision is necessary.

Fig. 292.—Corridor of State Mutual Building, Boston.

Enough light must be provided to light the halls well during the hours of darkness. What would be a very good intensity of light in a hall in the hours of darkness would seem rather gloomy during the hours when certain portions of the hall were lighted with daylight. It will therefore usually be necessary if any artificial light is employed during the daytime to use as much

then as is needed at night in order thus to avoid a gloomy appearance in the hall.

There is room for some argument as to whether reflectors are necessary or advisable where a row of pendants are located as in Fig. 292. It may be argued that since the object of hall lighting is to make the whole appear cheerful, it is as necessary to light

FIG. 293.—Corridor of Board of Trade, Boston.

the ceilings and high side walls as the floors. It must be remembered, however, that the lamps themselves are located very near the ceiling and high side walls, while they are some distance from the floor and that if no attempt is made to alter the natural distribution of light, the ceilings and high side walls will receive much more light than the floors with the result that the floors may appear rather dark and spoil the whole effect.

For this reason reflectors are usually advisable in the ordinary office building hall such as shown in Figs. 292 and 293 since by their use a fairly even illumination of ceilings, walls and floor can be secured. In case enclosing globes with 4 inch holders or larger are used, small reflectors which slip directly on the lamp

FIG. 294.—Main floor H. W. Hillman Building, Los Angeles.

bulb can be secured which add to the downward illumination very much. Some such reflectors are of the prismatic type and others are of metal with either bright metal or white enamel reflecting surface. A very small opaque reflector is permissible inside of a ground glass diffusing globe for the reason that

the diffusion in the globe with a small reflector will disguise the fact that the reflector is opaque and the ceiling above will not be seriously darkened.

There are certain classes of public building halls which are in the nature of lobbies where it is sometimes desirable to throw light upward to illuminate architectural or artistic features of high vaulted ceilings. Such cases are taken up under the head of lighting of lobbies.

FIG. 295.—Corridor Hotel Somerset, Boston.

A case somewhat of this character is presented in Fig. 294 which is a corridor on the first floor of the H. W. Hillman Building, Los Angeles. Here the lighting is by means of lamps enclosed in sand blasted globes placed on high brackets along the side walls in a position where they illuminate floors and ceilings about equally. In a hall of this kind which has white marble finish and light floors it is easy to produce a cheerful appearance and no special attempts to direct the rays of light are necessary with side brackets located as shown.

Another example of this is the corridor of the Hotel Somerset, Boston, Fig. 295. Here the lighting from the brackets is supplemented by lamps located in a cove above the cornice and throwing their light to the ceiling. This indirect lighting, although pleasing, is an expensive method of producing results for the reasons mentioned in Chapter XX in connection with the Hotel Jefferson, St. Louis.

CHAPTER XXII.

THE LIGHTING OF THEATERS.

Under this head it is proposed to take up simply the lighting of that portion of the theater occupied by the audience. Stage lighting is a special branch which has received due attention from specialists in that line. In theater lighting the lamps must be kept as much out of the sight of persons in the audience as possible; that is, they must be placed so that the rays from the

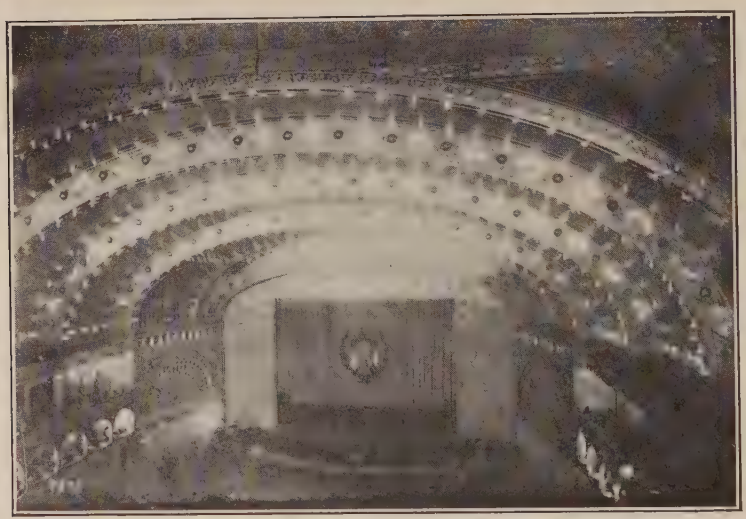


FIG. 296.—Auditorium Theater, Chicago, from balcony.

lamps will not enter the eyes of persons seated in the audience who are looking toward the stage. Of course to conceal them absolutely would be an impossibility. Next after keeping the lamps out of the line of ordinary vision the most important thing in theater lighting is to deliver as much light as possible on the audience from lamps located very high above the audience.

For this reason efficient reflectors can be used to great advantage although in a great many cases they are not used; which results in a great loss of light.

The statement made in Chapter XVIII as to the angle with reference to the eye that lamps must be placed if the eyebrow is to shade the eye can be considered here with advantage.

Fig. 296 shows the Auditorium Theatre in Chicago which is famous as a ruiner of eye sight. A prominent Chicago occulist states that the lighting of this theater has brought him thousands

FIG. 297.—Side view, Auditorium Theater.

of dollars worth of business because of the disastrous effect it has on the eyes of the persons going there habitually. As seen from Fig. 296 the principal lighting is done by bare lamps placed on the arches so that the persons in the audience in the balconies must take the glare from this entire array of lamps. Even persons with strong eyesight experience some discomfort if obliged to face these lamps for a whole evening. This is used considerably as a music hall and consequently the lamps are not always turned out during a performance as in a theater.

Fig. 297 is another view of the auditorium theater taken

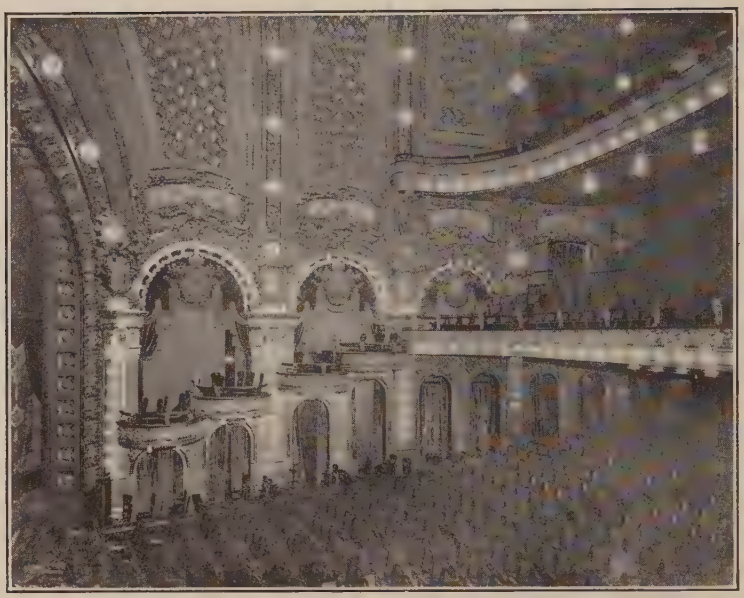


FIG. 298.—Majestic Theater, Boston.

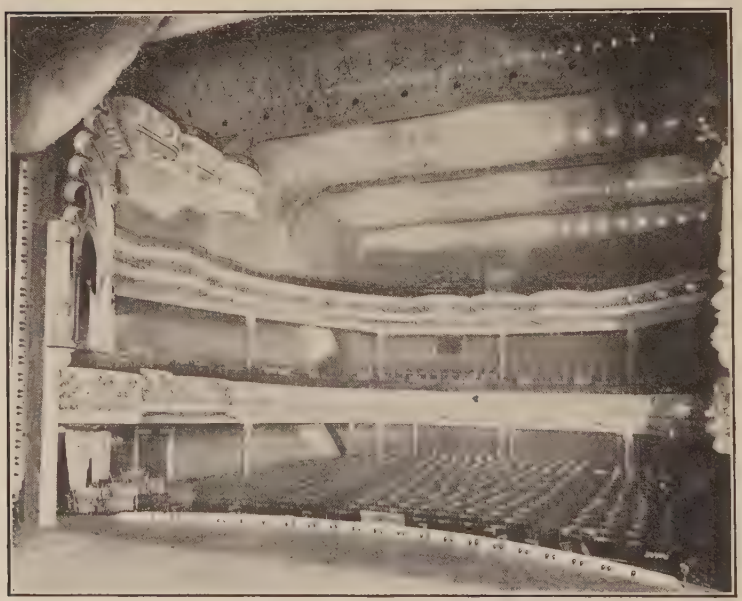


FIG. 299.—Theater with concealed lights.

from one side. It shows how easy it would have been to locate the lamps behind the arches so that they would have been out of sight of the audience and at the same time would effectually light the theater. No reflectors are used on these lamps. This is a case where a good reflector would greatly increase the illumination on the audience. With bare lamps the ceilings must be depended upon to reflect down the large amount of light which strikes them. Much of this light must be reflected back and forth between various surfaces several times before it reaches the audience and

FIG. 300.—Orchestra Hall, Chicago.

is virtually lost in the process. With lamps placed so far above the audience as is necessary in a theater, reflectors which will converge the rays of light and throw them down are absolutely essential to economy.

Fig. 298 shows the Majestic Theatre, Boston, where Holophane hemispheres are located on the arches. In this case the arches are not as nearly in the ordinary line of vision as in the Chicago Auditorium, and the arch lamps are further rendered as inoffensive as any exposed lamps can be by covering with the diffusing hemis-

pheres. This is as pleasing and artistic an arrangement as can be found for lamps placed in view on the arches. As theater owners so frequently clamor for plenty of exposed lamps for decorative effect, this is an easy way to give it to them with a minimum of injury to the eyes of theater goers.

Fig. 299 is a view from the stage of a theater in which the lamps are properly located behind the beams of the ceiling and along the front of the balconies. Here also is a case where reflectors would materially increase the efficiency. The lamps if

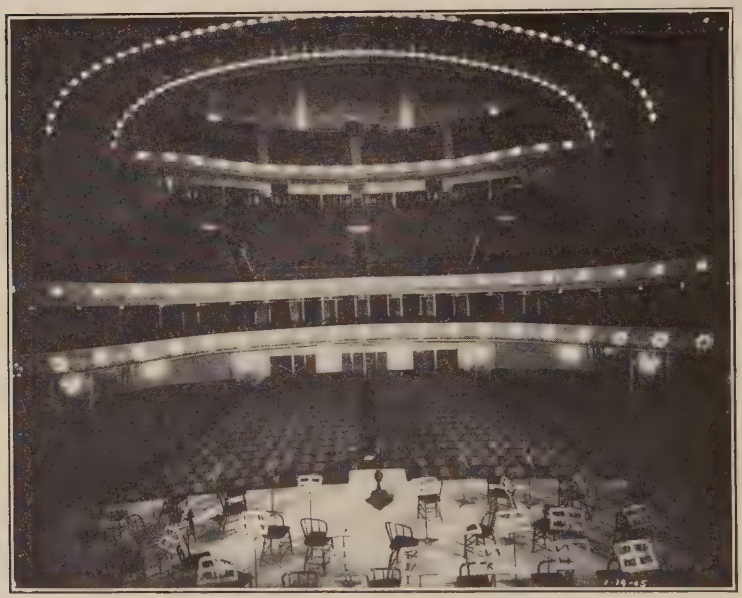


FIG. 301.—Orchestra Hall, Chicago.

so equipped should be placed at an angle of about 45 degrees instead of horizontal as they are shown.

Figs. 300 and 301, show the lighting of Orchestra Hall, Chicago. Fig. 300 taken from a balcony shows the lamps to be almost invisible to persons in the audience except that a small amount of reflection from the ceiling can be seen and the lamps along the front of the balconies at each side are visible. Fig. 301 taken from the stage shows better how the lamps are located behind the arches so as not to annoy the audience. If the lamps along

the fronts of the balconies could be concealed in a cove, especially around the sides where they are exposed to those sitting on the opposite side of the balcony, it would be another marked improvement. No reflectors are used on the lamps high up on the arches in this theater. The amount of light delivered to the audience could be much increased by their use.

Part of the lamps in the audience room are usually turned out during theater performances. Nevertheless, the lighting arrangements should be such that if it is desired to turn all lamps on during the entire performance it can be done without straining the eyesight of persons in the audience.

The frontispiece shows the large audience-room in the new Engineering Societies' Building in New York, which is a beautiful example of semi-concealed lighting. The principal light comes from the ceiling. In the centre of each of the three spaces there is a large panel of diffusing glass, behind which are placed nearly 800 reflector lamps. By reflector lamps is meant the turnip-shaped incandescent lamp with a silvered mirror surface applied to its top, which acts as a reflector. It would have been much better to have used standard lamps with some sort of a reflector, but the space was too confined to allow this. The objection to reflector lamps is their comparative inefficiency if their life is reasonably long, and their short life if they are made of reasonable efficiency.

In addition to the lighting from the ceiling in this auditorium, there is a row of ceiling lamps back of the stage and there are clusters of lamps around the sides of the balcony and orchestra floor. These clusters should not be turned on except when the audience is assembling, as the light is otherwise apt to shine in the eyes of some of those in the audience.

CHAPTER XXIII.

THE LIGHTING OF CHURCHES.

The lighting of churches is more difficult than that of theaters. It is even more important to keep light from shining in the eyes of the audience in a church than in a theater because in a church most of the light is turned on as long as the audience is present. At the same time it is more diffiult to conceal the sources of light in a church than in a theater because the usual church architecture makes it difficult. The old plan of lighting churches by means of immense clusters of lamps mounted on central chandeliers so that the light must fall directly in the eyes of all except those seated well forward in the audience must give way to some more hygienic, sensible and artistic method. To all persons but those with the strongest of eyes the facing of artificial light steadily through church services is uncomfortable and injurious.

Fig. 302 shows the lighting of the Second Presbyterian Church in Chicago. This a most remarkable example of lighting and illustrates how far attempts at artistic lighting can be carried to the detriment of eyesight and of satisfactory lighting. The lighting fixtures which are certainly of original design have incandescent lamps placed upright in saucer shaped devices. If the fixtures were judged from a purely engineering standpoint one would imagine that the object aimed at was to throw as much light upward as possible. This latter result must have been fairly well secured because we note on a chandelier at the extreme right that these saucers have been placed on top of the lamps to act as reflectors for throwing the light down. There is entirely too much light in the ordinary line of vision of persons in the audience in this church. Not only are the lamps on the chandeliers in trying positions, to those in the balcony, but the whole situation is made worse by the decorative lighting around the pulpit and organ, which must be looked at during the entire service by everyone in the audience who makes any pretense to

appearing attentive to what is going on. The lighting of the galleries in this church should have been accomplished by lamps located back in the arches where they would be out of sight of as much of the audience as possible. The lighting of the center of the main floor could be well accomplished by specially designed fixtures of the type shown later in Figs. 309 to 314, these fixtures being arranged so that a person sitting behind would receive no more light than would shine through a very dense art glass. In other words, persons in the audience should receive light from above and behind rather than from the front.

FIG. 302.—Second Presbyterian Church, Chicago.

Fig. 303 shows the First Church of Christ, Scientist, Chicago, which has an unusual architectural design and consequently permits of unusual church lighting arrangements. The lighting is done by lamps placed on the arches and around the central dome. Frosted lamps should always be used in such a case. The design of the lighting is fairly good from a hygienic standpoint because but a small amount of light direct from the lamps enters the eye of most persons in the audience. It would be much better, however, were deep reflectors used on the lamps on the arches, thus shading the lamps and increasing the amount of light thrown down. It would be desirable also to have de-

signed the dome to permit of the lamps being pointed downward and placed in some common type of translucent reflector to direct the light down. In an audience room of such shape as this there appears to be no opportunity for arranging lamps so that they will be entirely out of sight of more than two-thirds of the audience. The only method of treatment is therefore to make liberal use of deep reflectors or diffusing globes.

Fig. 304 shows the lighting of a Chicago cathedral in which lamps are placed high up on the main arch and on the pillars. The pillar lighting is objectionable for reasons before emphasized.

FIG. 303.—First Christian Science Church, Chicago.

Too much light shines into the eyes of the audience. The same thing is true of the lighting of the altar. The lamps high on the arch are sufficiently above the range of ordinary vision to be unobjectionable. Lamps so located should have powerful concentrating reflectors giving a light distribution like that shown in Fig. 35 in order to deliver as much light as possible down on the pews. In a church of this kind in which the pews all face one way it would be an easy matter to conceal most of the useful lighting behind the various features in the architecture so that it would not injure the eyes of those in the audience.

Fig. 305 shows the lighting of a small church, this view being

from the pulpit. This is not by any means to be taken as an example of model lighting, but is shown to give some ideas as to how lights can be arranged so as to be out of sight of the audience. The lighting as it stands represents simply a successful attempt to remodel with a small amount of money a very unsatisfactory previous arrangement. The principal lighting of this church auditorium was originally designed to be accomplished from the central basket form of chandelier seen. This basket was of copper wire gauze and had a number of bare incandescent lamps located inside of it. The copper wire gauze was designed

FIG. 304.—Chicago Cathedral.

to act as a diffusing covering which it did to a certain extent but with an enormous loss of light. As it was necessary to increase the illumination without placing any more load on the circuits and necessitating the expense of rewiring, the following changes were made. The candle-power of lamps in the central chandelier was reduced one-third and the lamps were placed outside the basket and equipped with prismatic reflectors as seen in Fig. 305. This failed to bring up the illumination on the sides of the room sufficiently for comfortable reading. To accomplish this latter purpose the lamp shown between the beams at the extreme left was installed with a prismatic reflector; a corresponding

lamp being placed on the other side of the audience room. At the pillars in the rear there was previously a lantern fixture covered with copper wire gauze, the absorption of which was not less than 50 per cent. The illumination in the rear of the room being entirely unsatisfactory, two lamps were placed in angle wall sockets pointing downward at an angle of 45 degrees and

Fig. 305.—Lighting of a small Church, remodeled.

equipped with powerful prismatic reflectors so as to throw light from behind on those seated in the rear of the room. The result of these changes was to make the amount of illumination in all parts of the room fairly satisfactory. The central chandelier throws too much light in the eyes of those seated in the back part of the room and for this reason is objectionable. A larger

proportion of the total lighting should be done from behind, leaving the chandelier to serve mainly a decorative purpose. Artistic ceiling fixtures placed on the walls or on the slopes of the roof between beams could be used in place of the simple wall socket shown in Fig. 305. Conditions as they stand could be improved by substituting for the reflectors used on the chandelier a deeper type of reflector which gives a wider distribution of light such as shown in Fig. 37. This would hide the bare lamps from those seated in the rear seats so that they would receive only diffused light through the reflector and would cause the chandelier lamp to deliver more light to the sides of the room and less immediately under the chandelier than is now the case.

FIG. 306.—Fifth Christian Science Church, New York.

Such reflectors were not available until after this work was done.

Fig. 306 shows another common method of church lighting also open to the general objection of too much light from the lamps shining in the eyes of persons in the audience. As far as simple efficiency goes, the arrangement shown gives excellent results, the lamps on the chandeliers being equipped with concentrating types of prismatic reflectors which deliver a large percentage of the light down on the audience. Frosted lamps should be used here.

Fig. 307 shows a church with bare gas jet brackets along the side walls and clusters of open flame burners over the organ and the choir. This is a good example of what to avoid as far as the

lighting of the front of the church is concerned. The lamps there are placed where everybody must look directly at them during the entire length of the service. They are so situated as to be not only tiring to the eye, but owing to the eye working with a small aperture, the ability to see the preacher is materially decreased. A canvass among the congregation would doubtless disclose the fact that many people were subject to headache when in the church and that owing to the fact that it would be easier to close the eyes than to look at the light, people were put to sleep, not necessarily by the sermon.

FIG. 307.—Church with bare gas jets.

Fig. 308 shows the interior of the First Church of Christ, Scientist, Pittsburg, lighted by Nernst lamps hung high. Since the Nernst lamp, like an incandescent lamp with a reflector, throws so large a proportion of its light down as seen in Figs. 173 to 176, it is well suited to being hung high. Because the lamps are placed so high the lighting of this church is the least open to criticism of any of those shown. It is the best that can be done without concealing the lamps.

With ordinary fixtures there are only two methods of church lighting which represent even an attempt to avoid the very objectionable feature of light shining in the eyes of the audience.

One method is to conceal the lamps behind architectural features such as beams and pillars in a way that the light will shine down and forward but cannot shine backwards so as to fall on the eyes. This method is good, but there are many churches or parts of churches where it cannot be done. Simply placing the lamps very high, while it is much better than having them low where they cannot be avoided by the eye nevertheless is open to serious objection. As long as artificial light can fall steadily for some time on the eyeball, no matter from how high an angle it will produce eye strain. The light must come from such an angle that

FIG. 308.—First Christian Science Church, Pittsburg.

the eyebrow shades the eyeball. This critical angle when a person is seated looking forward as in a church is about 25 degrees from a perpendicular drawn through the eyeball, as explained in the chapter on the lighting of public halls and lodge rooms, Fig. 263. To light a church well from a hygienic standpoint then, we must have no rays of light shining backwards at an angle of more than 25 degrees from the perpendicular. The lighting must therefore be done by light shining down sideways and forward toward the pulpit.

To accomplish this where the light cannot be shaded by architectural features or placed on back walls and ceiling slopes, a

special design of fixture is necessary. Some suggestions along this line are given here to show the general principles which must govern the design of such fixtures.

Fig. 309 is a side view and Fig. 310 a rear view of a suggested form of fixture. In Fig. 309 the side *A*, *B*, is placed toward the pulpit and the side *C*, *D*, toward the audience. It is made up in box form with the bottom open. The sides are art glass of any desired design. The side, *C*, *D*, should be of very dense, nearly opaque, glass, since this is the side which acts as a shield to protect the eyes of the audience seated behind it. The other sides need not be as dense unless uniformity for the sake of ap-

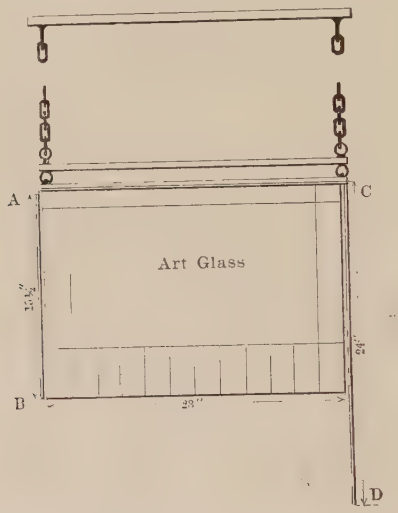


FIG. 309.—Side view of art glass fixture for church lighting.

pearances is wanted and that is mainly a matter of taste. A sectional side view of this fixture is seen in Fig. 311, which shows the arrangement of one of the lamp sockets and reflectors as viewed from the side. Fig. 312 is a sectional view from the rear showing both of the lamp sockets and reflectors as they would appear from the rear if the art glass of the side *C*, *D*, were removed. The reflectors selected should preferably be a fairly concentrating type of prismatic reflector such, for example, as was shown in Figs. 31 and 35. This fixture is designed for two lamps of 32 or 50 candle power each. The reflectors are pointed so as to throw the light forward and sideways. The side *C*, *D*, keeps the

light from shining backward at more than the critical angle of 25 degrees except the little going through the dense art glass. The side A, B, and those joining it are made shorter so as not to interfere with the light thrown forward and sideways. In order to accomplish the shading and avoid excessive height of the side C, D, the lamps should be placed close to this side as shown. The dimensions are given on the drawings. This is as small as the fixture should be made for two 32 candle-power lamps because if the side C, D, is made less than 24 inches, it will not shade the eyes from the lamps if allowances are made for ordinary inac-

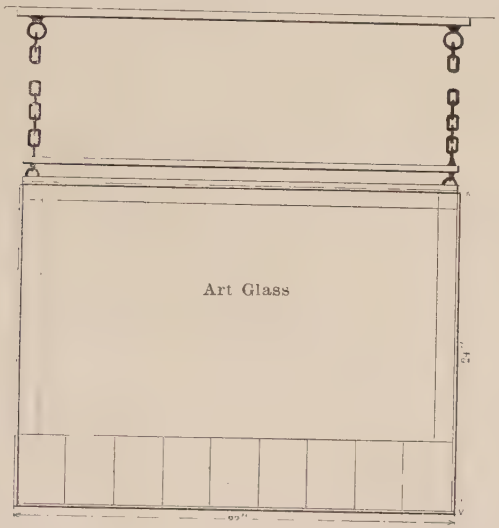


FIG. 310.—Rear view of art glass fixture for church lighting.

curacies of manufacture in such goods. It can, of course, be made as much larger as seems desirable. The fixture arranged as shown with reflectors of the kind shown in Fig. 36 will light an area extending forward toward the pulpit, a distance approximately equal to the height of the fixture from the floor and double that distance sideways. There is room for a third lamp without increasing the width. It is, generally speaking, advisable to hang these fixtures rather low and use a number of them to cover this area to be lighted rather than to place a few large fixtures high up. There is a great gain in economy of light by hanging them low since the intensity of light on the pews varies

inversely as the square of the distance of the fixtures above them. The usual objection to low chandeliers (that the light is brought too nearly in the line of vision), does not hold here because of the shading effect of the dense art glass backs of these fixtures.

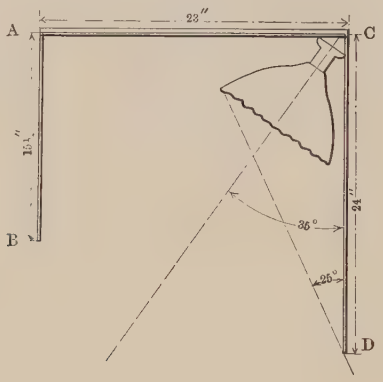


Fig. 311.—Sectional side view of church fixture.

The general character of the fixture shown in Figs. 309 and 310 is similar in external appearance to the fixtures shown in Chapter XXVI on the Lighting of Stores, Fig. 343.

The same principle can be carried out in other designs, but

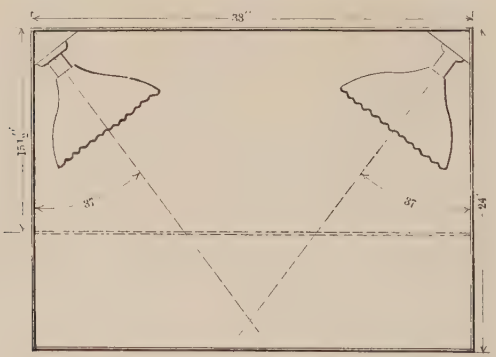


Fig. 312.—Sectional rear view of church fixture.

only two others will be shown here. The lantern design lends itself well to the carrying out of this principle as shown in Fig. 313 which is a very plain lantern design and also in Fig. 314 which is more elaborate.

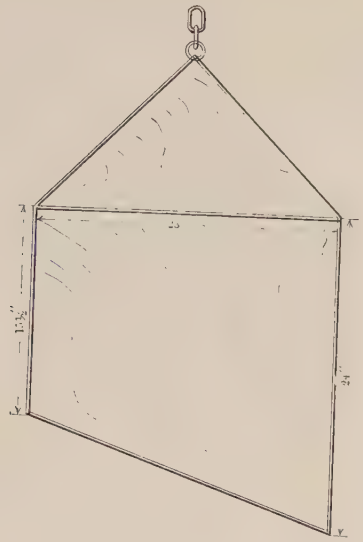


FIG. 313.—Church fixture in lantern design, side view.

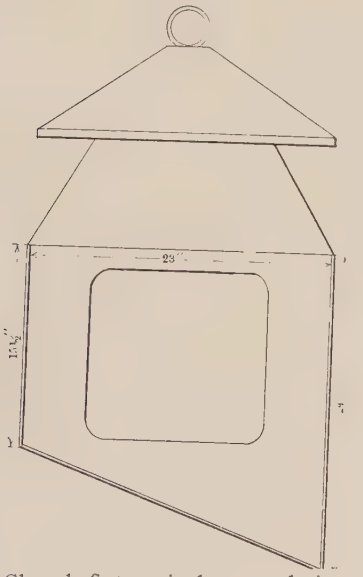


FIG. 314.—Church fixture in lantern design side view.

CHAPTER XXIV.

THE LIGHTING OF LIBRARIES, READING AND SCHOOL ROOMS.

In lighting library reading rooms the principal light is of course needed on and near the reading tables. A very common method of lighting reading room tables is to use green opal desk shades on desk lamps ranged along the center of a table with lamps from 12 to 18 inches above the table top; the chairs for reading being ranged along both sides as in Fig. 315. This arrangement is not altogether efficient or satisfactory. Most green opal desk shades concentrate light immediately under the shade and when placed over the center of a reading room table the result is a brilliantly lighted center (which is of no use to any one), and comparatively dark edges of the table. The outwardly pointed reflectors at the ends are extremely bad because the light shines directly in the eyes of the person seated at the end of the table. In order to spread the light more evenly over the table in Fig. 315 the desk shades should be raised a little higher from the table so as to light it more uniformly and inside of the green opal desk shades a globe or reflector should be used which would distribute most of the light at and near an angle of 45 degrees from the vertical. This can be done by using a desk shade with 3 .25 inch holder and placing inside the desk shade on a 2 .25 inch holder a prismatic reflector of the type which gives a maximum candle-power at an angle between 30 and 45 degrees from the vertical such as shown in Fig. 37 using frosted lamps. Another excellent plan for reading table lighting in a library is to place the lamps on a chandelier above the table clear out of the line of ordinary vision of the readers. This plan is likely to give the readers less trouble from the glare of reflection from the paper than when the low table lamps are used. If the reading tables are lighted from chandeliers, however, pains must be taken that the chandeliers are designed and equipped to give the desired results.

For example, Fig. 316 shows a library reading room in which the lighting is done by chandeliers above each table. The arrangement is decidedly faulty, however, evidently due to a lack of knowledge of the characteristics of the different reflectors on the part of those responsible for the installation. The chandelier with the bottom attachment consisting of a cluster of incandes-

FIG. 315.—Common faulty method of reading table lighting.

cent lamps under a flat opal reflector (see Fig. 151) is both inartistic and inefficient for this particular purpose. The bottom cluster should be left off entirely or if used, should be placed inside of a large opal dome. Such a small reflector as this over a cluster of lamps allows too large a percentage of the light to escape horizontally. The preferable arrangement would be to have the chandelier with sockets pointing about 10 degrees

from the vertical equipped with reflectors giving a distribution such as shown in Figs. 19 and 21 which will concentrate most of the light around and on the reading table. The opal reflectors with which the chandelier arms are equipped in Fig. 316 are excellent for general distribution below the horizontal when placed vertically as seen from Fig. 23, but do not concentrate enough light below the tip of the lamp.

Fig. 317 shows a reading room which is an excellent example of how not to do it as far as the lighting is concerned. The chandelier over the table is equipped partially with upright incandescent

FIG. 316.—Poor design of chandelier for reading table.

lamps, and partially with lamps at an angle of 45 degrees in etched glass shades. The arrangement permits about half the light to escape toward the ceiling. Around the sides of the room are brackets placed high. The location of the brackets is excellent, but their equipment is open to the same objections as that of the chandelier. Too much light is allowed to escape toward the ceiling and even if expense were no object the arrangement is bad because it permits of too much undiffused glare from incandescent filaments. The least that could be done in a case like this would be to enclose all lamps in diffusing globes.

Much more light could be secured for reading purposes by pointing the lamps at a different angle, say downwardly about 10 degrees from the vertical, and placing them in deep reflectors such as shown in Fig. 22 or 38. The area to be covered is large. These reflectors would distribute light well over all angles below 45 degrees from the horizontal and would be deep enough so that the light would not be directly visible except to those sitting near the lamp. Were it undesirable to darken the ceiling as much as would be done by deep opal reflectors, and if prismatic

FIG. 317.—Wastefully lighted reading room.

reflectors were not used, dome shaped reflectors of sand blasted glass such as in Fig. 73, could be used which would not throw so much light below the horizontal as opal reflectors, but would nevertheless give considerably more than those now on the lamps and at the same time be of very artistic appearance.

Fig. 318 shows a school room lighted by gas mantle burners. In a school room it is desirable to avoid all unnecessary glare and provide a good working light at all desks. Chandeliers must therefore be located at frequent intervals and equipped with

shades or globes which will direct most of the light downward in the immediate vicinity of the chandelier, while avoiding glare as much as possible. This is fairly well accomplished in this case by the use of diffusing globes which direct the light downward in the manner shown in Fig. 120. It will be evident from the spacing of the chandeliers that a better globe might have been selected (such as Fig. 123) which would throw the light more at an angle of 45 degrees instead of directly downward, as is the case of the globe here used. The illumination is good and the diffusion is excellent.

FIG. 318.—School room lighted by gas.

Fig. 319, showing the library of the University Club, New York, is an example where efficiency has been greatly sacrificed for the sake of art. Chandeliers equipped with upright electric lamps are much better as illuminators of the ceiling than as producers of useful light. In order to deliver more light below the horizontal, these chandeliers have been equipped with globes of the kind shown in Fig. 85 which accomplish that result as well as it can be accomplished with upright lamps on a chandelier of this kind. On the whole, it is questionable whether such a

chandelier is sufficiently superior in artistic appearance to one with pendant lamps to make the extra cost of illumination by means of it worth while.

The tables are lighted as seen, by stand lamps placed upon the tables. The remarks already made about table lamps used for library table lighting apply to the small stand lamps shown on the tables between the book shelves at the left. As to the large ornamental stand lamp shown on the central tables under the chandeliers,

FIG. 319.—Library of University Club, New York.

something further may be said. These lamps are intended both for decorative and useful purposes. Where large decorative shades of this kind are employed a very feasible and efficient arrangement is to place inside of the shade two lamps pointing in opposite directions at an angle of about 45 degrees. These lamps can be equipped with concentrating reflectors, such as shown in Figs. 20 or 32 and with frosted bulb lamps. When placed in the center of a table the lamps should be pointed length-

FIG. 320.—Wasteful table and shelf lighting.

FIG. 321.—Good plan for shelf lighting.

wise of the table thus securing a good illumination over most of the table.

Fig. 320 shows a very inefficient and unsatisfactory chandelier for the lighting of a library reading table. This chandelier is one of the kind designed entirely for ornamental purposes without any regard to illuminating effect. The lamp on the bottom tip of the chandelier would be of considerably more use to light the table if it were equipped with an opal reflector instead of being enclosed in a dense opal globe. The lamps on the chandelier arms, instead of having globes or reflectors for directing the light downward, are bare so that a great deal of the light is wasted on the ceiling as shown by Fig. 16.

Fig. 321 shows an excellent plan for the lighting of the shelves in a library. On the first floor the lamps are placed in large opal domes near the ceiling. A characteristic of the opal dome is that it gives a wide distribution of light at all angles below 45 degrees as shown in Fig. 21. On the second floor of this library the shelves do not extend to the ceiling, consequently the lamps are placed on pendants which bring them a little above the level of the tops of the shelves. The three reflectors best suited to this work are the opal dome, the fluted opal cone and the prismatic reflectors which give a wide distribution such as Fig. 37.

CHAPTER XXV.

CAR LIGHTING.

The efficient electric lighting of steam railroad cars is a matter which has received but little of the attention which its importance deserves. Steam railroad cars, up to present writing, have been almost invariably equipped without any reference to delivering the most useful illumination for the money expended and this too, in spite of the fact that frequently the source of current supply is a storage battery with a limited capacity. If more attention were paid to the efficiency after the current was delivered to the lamp, it would materially help out the amount of useful service that could be obtained from a given size of storage battery, as cars could be well lighted with less electrical energy. In the case of electric cars, it is not so much the question of efficiency as of general effect and good illumination without blinding glare.

Fig. 322 shows the interior of a private electric car which can be taken up for discussion to illustrate some of the points which will be brought out. This car in addition to having an ample supply of incandescent lamps has also an arc lamp as seen which is entirely out of place in a car of this kind and will be left out of account. The incandescent lighting is accomplished by a row of frosted bulb incandescent lamps along each side of the car. For an electric car where efficiency is no object the arrangement is fairly good. The frosted bulbs very much reduce the glare which would be received from a row of clear bulb lamps so located and there is no particular need of increasing the efficiency by the use of reflectors although the shading and diffusing which would be accomplished by an opal or prismatic reflector would be very desirable. If this were a steam railroad car drawing its electric lighting current in whole or in part from a storage battery, the economy aspect of the case would be quite different. These lamps should then be equipped with reflectors because of the greatly increased amount of light that could then be delivered at the seats as well

as for diffusing and shading reasons. The location of the lamps which would bring them over the seats of an ordinary railroad coach is excellent. The reflector selected should be one which would come down well over the lamps so as to diffuse the light and prevent it from blinding anyone looking the length of the car, such, for example, as in Figs. 20, 36, or 38. Opaque metal reflectors would manifestly be out of place in car lighting so that the choice lies between opal and prismatic glass if we leave out of account reflectors of sand blasted glass which do not modify the distribution of light sufficiently for this particular purpose. Opal

FIG. 322.—Private electric car.

reflectors have the advantage of being smooth and so much more easily cleaned than prismatic reflectors. They have a disadvantage strongly urged by some railroad men who have had experience with them that they show very badly the dirt which collects upon them between cleanings. Prismatic reflectors, while not so easily cleaned, do not look as badly when dirty as opal, because the dirt collects in the bottoms of the prisms where it is not noticeable. After all, the cleaning of a prismatic reflector is not very difficult if the cleaner is provided with a stiff brush and brushes lengthwise of the prisms.

No ordinary flimsy shade holder should be used for holding reflectors in car lighting. A brass or bronze holder fitting over the socket, as do the bronze husks shown in Fig. 322, should be used. This holder is fastened directly to the ceiling independently of the socket so that the weight of the reflector will not pull the socket to pieces. On Pullman cars the berths interfere with such a location of lamps and those for the general lighting of the car must be placed in the center, being usually grouped around the gas light. With lamps so placed, reflectors giving a maximum candle-power at about 30 to 45 degrees from the vertical would be best assuming the lamps to be placed vertical. If placed at angles radiating from the gas fixture, more concentrating reflectors should be used, and the lamps should be pointed at the seats; not up and down the aisle.

Some day-coaches are provided with lamps on brackets located high between each window. In this case also, reflectors giving a maximum candle-power from 30 to 45 degrees from the vertical should be used if the lamps are placed vertical. With such bracket lights considerable light must necessarily be lost because of the failure of the woodwork to reflect part of the light which goes in that direction.

In the lighting of dining cars, the principal thing is to provide a lamp at each table so arranged and so equipped with reflectors as to concentrate nearly all of its light on the white table cloth. With well lighted tables, the balance of the car will take care of itself. This table lighting can be accomplished by artistic brackets extending but a short distance from the side of the car, over each table and with lamps pointed down toward the table top. If desired, the subdued effect in table lighting so much sought for recently can be obtained by proper shading of the lamp, always remembering, however, that the concentrated beam of light from the reflector on to the top of the table must not be interfered with, however much the lamps may be shaded from the eyes of a person looking the length of the car. It goes without saying that all brackets and other fixtures used in car lighting must be short and substantial.

Fig. 323 is a remarkable example of the small difference there may be between the right and wrong way of lighting a dining car. In this illustration there is a two-light bracket over each table. This bracket, however, instead of being properly equipped with

a lamp in a deep reflector which would concentrate the light on the table and shade it from the eyes of persons seated some distance away, has two lamps in reflectors giving a very wide distribution and these lamps are pointed away from the tables. The result is that only a very small per cent. of the light of the lamp is directed on the table top. The reflectors do not act to diffuse or shade the light and the whole arrangement is much less efficient and much more trying on the eyes than it would be with the very small changes mentioned. The gas lighting

FIG. 323.—Dining car.

in this car is by means of the standard Pintsch gas fixtures fastened to the center of the car deck. This is about the only feasible arrangement for gas lighting in a car and is less trying on the eyes than some of the attempts to place gas or other lamps along the sides of the car. Electric lamps should be placed low along the sides of a car only when thoroughly shaded.

Berth lamps in sleeping cars, should always be shaded in such a way that persons facing them will not have the light shining in their eyes. This can be done by proper designing of

fixtures. On some electrically lighted sleeping cars this shading is accomplished very well. On others these berth reading lamps are entirely exposed and are very trying on the eyes of anyone who must face a row of them an entire evening. This is true whether the person is actually looking at the light or not

CHAPTER XXVI.

STORE LIGHTING.

The requirements of a small store in a country town naturally differ considerably from those of the immense department stores of the city. The requirements of the small store will be taken up first.

When incandescent electric lighting was first introduced in small stores the usual plan, and one that is still in very common use in country and suburban villages was to hang a row of bare incandescent lamps on drop cords at regular intervals the length of the store over each counter, thus making in the ordinary store which is 20 to 25 feet wide two or three rows of incandescent lamps the length of the store. These lamps are usually hung about six or seven feet above the floor or a little above the heads of clerks and customers. The same general arrangement is common with gas and oil lights in such stores. The whole effect is crude and the apparent illumination is nowhere near what it might be with other arrangements. In the lighting of a store, unlike the lighting of a warehouse, it is not simply a question of how much light can be obtained on counters and shelves, but it is a question of the general impression the lighting of the store makes upon the public. The lighting of stores is partially in the nature of advertising, as is recognized by all the most progressive merchants in both large and small towns. Let us therefore investigate the little store lighted with the rows of bare incandescent lamps or gas burners after the manner described and see what can be done with it. The first objection to be found is that a person looking the length of the store is partially blinded by the bare lamps which come directly in his line of vision. As a result, the store appears darker than it really is because of the fact that the bright light prevents the seeing of things near the light for the reasons explained in the chapter on Light and the Eye. The second objection is that

the bare lamps look undeniably crude and sickly. This is more true of incandescent electric lamps and open flame gas than of gas mantle burners. To simply enclose these bare electric drop lights or gas jets with globes of frosted or sand blasted glass would improve the general effect decidedly. The crudity of the bare lamp filaments or gas jets and the blinding effect produced by them can thus be relieved and the light coming from the larger surface of a diffusing globe is better from the standpoint of advertising and general appearance. The next step in improving the lighting would be to raise the lamps from a height of six or seven feet to a height of from eight to ten feet. When this is done reflec-

FIG. 324.—Store with efficient lighting.

tors should be used as in Fig. 324, in order that sufficient light may be delivered on the counters. By using efficient reflectors over the lamps, the downward illumination is increased more than enough to compensate for the raising of the lamps to a higher level, so that the illumination on the counter will be better than it was before. At the same time the lamps will be raised out of the line of vision so that they do not interfere with seeing across the store and the store will appear on the whole much better lighted than with the lamps hung low without reflectors.

The distribution of light with the reflectors seen in Fig. 324 is given in Fig. 45 and is probably the best that could have been selected for that location. With this shape of reflector frosted tip lamps should always be used. Opal reflectors, such as in Figs. 19 and 21 would give a good light distribution, except that they darken the ceiling more than is desirable for a cheerful, well lighted effect. At the same time that the lamps are raised the merchant may see fit to modernize his store lighting still more by placing the lamps on ornamental pendants rather than on the old drop cords. Fig. 324 shows a neat design of chain pendant. If pendants are not used, round, reinforced cord with dark silk covering offers considerable improvement in appearance over ordinary lamp cord with twisted wires.

By none of the common methods of electric lighting can as much good illumination be delivered to the counters of a small store for a given amount of electric energy as by the method just outlined, namely, by rows of pendant frosted incandescent lamps equipped with proper reflectors and placed at frequent intervals over the counters and about eight or ten feet above the floor. The arrangement besides being efficient also looks well, especially when frosted bulbs are used. The same principles can be used in gas lighted stores by raising the gas burners and placing reflectors or directing globes over them. The fact that incandescent electric lamps by this method are placed so nearly above the things they are to illuminate more than compensates for their lower efficiency as compared with other and larger electric lighting units such as arc lamps, Nernst lamps and large high efficiency incandescent lamps. In the case of gas the individual burners are considerably more efficient than gas arc lamps or cluster burners, as shown in Chapter XIV. As soon as we begin to employ larger lighting units such as electric arc lamps, Nernst lamps, gas arc lamps or high candle-power incandescent lamps, the units must be raised higher above the counters to avoid blinding effect. Because of their fewer numbers, the large units must necessarily be placed a considerable distance apart as compared to small incandescent or gas lamps and hence farther from the surfaces to be lighted between lamps. This causes considerable loss in efficiency. There is nevertheless a certain advertising value about large lighting units which must not be overlooked and which is largely responsible

for their popularity in store lighting. Either electric or gas arc lamps in a store attract a certain amount of attention to the store and light the ceilings and high side walls to such an extent that the store may appear more brilliantly lighted to a passer-by than if it was equally well illuminated as far as the counters are concerned by incandescent lamps. Then, too, it costs less to install a few large lighting units in a store than to provide enough outlets for a lot of small incandescent or gas lamps. If small, common carbon filament incandescent lamps are bunched on a few chandeliers or clusters they are at the same disadvantage as any large lighting unit, that is, they are a long distance from the parts of the store between chandeliers, and the inherent low efficiency of the small lamps puts the chandelier arrangement at a disadvantage as compared to arc, Nernst or high candle power incandescent lamps placed at similar intervals. Shadows are more pronounced and annoying with a few high candle power units than with a large number of small ones. If a store is flooded with a great abundance of light, the inefficiency of lighting by large units as compared to distributed small lamps will not be felt so much as if the total candle-power of lamps provided is barely sufficient to give good results.

When we come to the use of large lighting units such as arc lamps and Nernst lamps, it must be recognized at the start that there is considerable difference in the distribution of light from these various illuminants. Both the Nernst lamp and the large high candle-power incandescent lamp equipped with a prismatic reflector throw most of their light downward, as seen in Chapters V and IX; being very similar to each other in this respect. The direct current enclosed arc lamp (see Chapter X) gives a large amount of light at from 15 to 60 degrees below the horizontal. Immediately below the lamp the candle-power is comparatively low. This suits it specially for lighting over a large area. With incandescent lamps equipped with reflectors or with Nernst lamps, each lamp should be placed as nearly as possible above the portion of the store which is to be lighted by it. A direct current arc lamp can be expected to light a larger area.

The alternating current arc lamp, except when equipped with a large and properly shaped reflector, (and it frequently is not), delivers so much of its light at angles near the horizontal as to put it at a decided disadvantage in store lighting when compared

with the Nernst and the direct current arc lamp. With only alternating current supply available therefore and if large units are to be used, the maximum efficiency is to be expected in store lighting by the use of Nernst lamps rather than ordinary types of alternating current arcs. The Nernst lamp is also steadier. The "gas arc" lamp, which is a four burner gas mantle lamp has a natural distribution of light very similar to the alternating current electric arc lamp which puts it at a disadvantage in store lighting as far as the percentage of its light thrown on the counters is concerned. This disadvantage can only be compensated for by providing a good deal more light than is necessary in the upper portions of the store in order that the lower portions may be properly illuminated. The price of gas may be cheap enough as compared with the price of electric power to compensate for this in some cities. There is also the question of the relative cleanliness and convenience of the two kinds of light and of the heat and products of combustion from the gas lamp. The heat may be an advantage in some seasons and a disadvantage in others. These are questions which it is out of the province of this book to discuss. The distribution of light from electric, gas and Nernst lamps is given in previous chapters. Users must weigh these results and draw conclusions according to their particular conditions and requirements as no general principles can safely be laid down, except that it is usually possible with electric lamps to deliver a larger portion of the total light produced where it is needed than with gas or oil lamps.

There is a great difference of opinion both among merchants and illuminating experts as to the color of light which should be used in stores of various kinds. It is a common opinion that the light which nearest approaches daylight is best for clothing and dry-goods stores. In other stores it is not usually considered that the color of artificial light used makes much difference. There are some who contend that even for dry-goods stores an artificial light similar to daylight is not necessary.

That the color of a piece of goods depends upon the kind of light in which it is seen and that in some cases a change in the kind of light makes radical changes in the apparent color of a piece of goods is a scientific fact upon which there is no room for argument. Some go so far as to maintain that goods should be sold under the kind of light under which they will or-

dinarily be used. On this theory, goods to be used mainly in daylight should be sold under daylight or artificial light which most nearly approaches white light, while goods ordinarily worn in the evening under the yellow light of electric incandescent or open gas flames should be sold under a similar yellow light, There are others who would lay aside the question of matching or selecting colors entirely and consider the question simply from a psychological or advertising standpoint. Some consider that yellow light like that from an electric incandescent lamp or open gas flame has a certain warmth and cheerfulness about its appearance which gives a more pleasing effect that can be obtained with a whiter light. Those who hold this theory maintain that a white light is cold and cheerless in its apppearance. On the other hand, some think the white light the more cheerful of the two. As this is a question upon which even the authors disagree and upon which there is room for so much variety of personal opinion, it will not be discussed further here except to point out some of the established scientific facts in regard to the color of different illuminants.

Of the common artificial illuminants, the old-fashioned open arc lamp approaches nearest to white light, or daylight. Daylight itself varies considerably. There is a greater proportion of red in its rays when the sun is low than at noon-day because the rays when the sun is low must pass through many more miles of air; the violet rays being absorbed by the air more than the red and yellow rays.

The modern enclosed arc lamp does not give a light as nearly approaching daylight as the old-fashioned open arc. The ordinary enclosed arc has an excess of violet. This excess of violet can, however, be largely corrected by the use of opal enclosing globes which filter out some of the excess violet rays. The use of small carbons in enclosed arc lamps also tends to make the light whiter and also to make it steadier, both of which objects are very desirable.

Next after electric arc lamps in approach to daylight come acetylene gas, mantle burner gas lamps, tantalum incandescent and Nernst electric lamps. The mantle burner gas lamp has a slight excess of green in its make-up which, like the excess of violet in the enclosed electric arc may interfere with color selection and matching unless it is compensated for by the use

of mantles and glassware designed to accomplish this. Certain mantles are said to do this to a large extent and opal enclosing globes also have a tendency to filter out the green rays just as they do the violet rays in the case of the enclosed electric arc.

In the case of the Nernst, high efficiency Gem carbon filament, and tantalum lamps we have illuminants which are midway between the yellow of the ordinary incandescent, open gas, and kerosene flames and the whiteness of daylight. They may be considered as in the nature of a compromise between these two. Their steadiness is in their favor when compared with electric arc lamps.

The ordinary carbon filament electric incandescent lamp, open gas jet and kerosene lamp are about the same in color and are farthest from white light of any of the common illuminants.

Taking up now some practical examples of store lighting arrangements, we have in Fig. 324 already mentioned, the general scheme of small store lighting which probably gives the best illuminating and artistic results for the money expended. In this case 187-watt Gem filament, high efficiency, frosted incandescent lamps in distributing prismatic reflectors are suspended in rows over each counter by ornamental chain pendants. Lamps of 125-watts would answer very well here, but of course would not flood the store with light as it is now and some of the advertising value of good lighting would be lost. In this store the wiring is in conduit placed on the ceiling in such a way as to be neat and unobtrusive. This arrangement places the lamps immediately over the places to be lighted, hence the high efficiency of the arrangement. The lamps are hung approximately 12 feet apart.

Fig. 325 shows a store fitted up as an automatic vaudeville parlor. The principal lighting is by means of lamps studded along the ceiling and by a row of brackets along the left side. The idea in this case of course is to attract attention to the place by the wealth of light displayed rather than to secure useful illumination. The arrangement is, however, very good for useful illumination. Enclosing globes, such as shown in Fig. 79, are used, which direct the light downward as well as diffuse it, so that it is inoffensive to the eye. The lamps are so well distributed that every corner of the room is well lighted.

It is sometimes the case that the lighting of a store or display

room by means of a large number of distributed incandescent lamps which give the best results from a purely economical standpoint is objected to by the owner on the ground that only a few outlets for electric wires have been provided in the original wiring of the building. The owner may dislike to go to the expense of rewiring the building or does not wish to run wires in exposed conduit or moulding as would be usually necessary to supply a lot of scattered incandescent lamps. One neat way of overcoming this difficulty is shown in Fig. 326 which is the carpet salesroom of a large Los Angeles store. Here the incan-

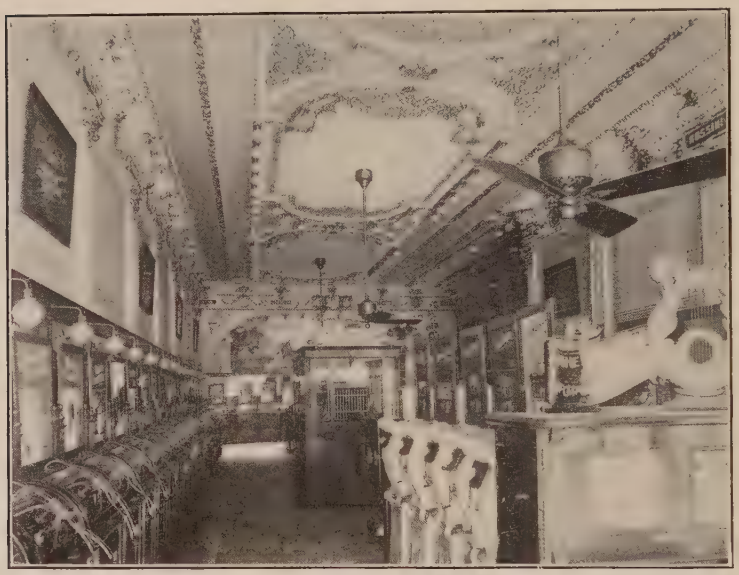


FIG. 325.—Efficiency and decoration well combined.

descent lamps are suspended on drop cords from a handsomely finished rectangular brass pipe which is hung horizontally near the ceiling with its middle under each wire outlet. This gives well distributed lighting, although in this case a more even distribution of light over the floor could have been obtained by the use of a prismatic reflector which would not concentrate the light so much as the one which is seen in the illustration which is a very concentrating form, similar in light distribution to Fig. 35. The distribution shown in Figs. 19, 29, 33, 37, and 43 would be better.

A modification of Fig. 326 which is sometimes used is to run wires in small brass tubes two or more ways from each outlet, these tubes being similar to those used in fixture arms, and terminating in lamp sockets.

Fig. 327 shows a very common method of store lighting by means of direct current enclosed arc lamps with opal outer globes. This may be considered as a good example of light properly placed. The direct current enclosed arc (see Fig. 184) gives a distribution of light which will in this case cause the maximum light to be thrown in the direction of the shoe

FIG. 326.—Distributed lighting from few outlets.

cases, which is desirable. From the shoe cases it will be reflected back to the customers' chairs, which is also desirable. The lamps have opal outer globes which tend to filter out the violet of the enclosed arc light and also diffuse the light so as to make it easy on the eyes of clerks and customers because the light comes from the entire surface of the globe rather than from a small area. As before explained, a store lighted with arc lamps as in Fig. 327 is not as economically lighted as it would be with rows of pendant incandescent lamps with proper reflectors well distributed over the store. There is, however, a

certain advertising value in the large arc lamp units, especially when they are seen from the street even though they may not be as good from an economical and artistic standpoint as distributed incandescent lamps with frosted bulbs.

Fig. 328 shows a good way of lighting a small meat market by means of one direct current arc lamp. The distribution of light from the direct current arc lamp is such as to throw a good intensity on the counter and toward the meat hooks. The lamp is equipped with a reflector and an opal inner globe only. In a case of this kind, an opal outer globe is not as neces-

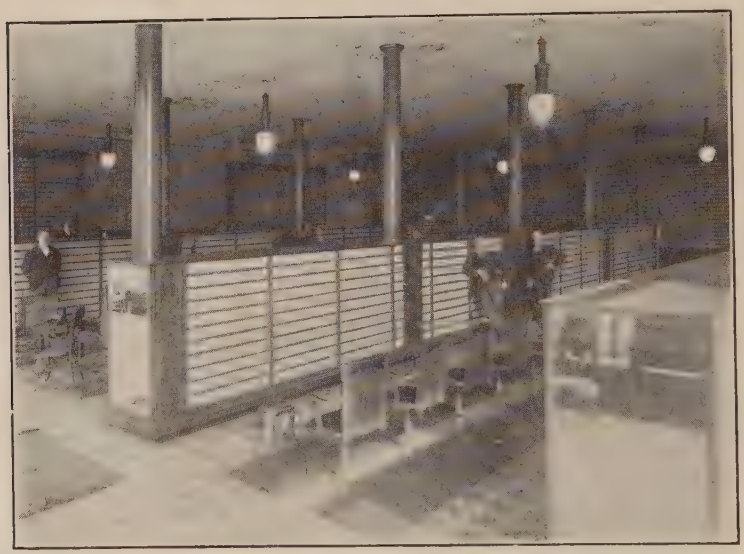


FIG. 327.—Arcs well placed in shoe store.

sary as in Fig. 327 because the lamp is so well out of the line of ordinary vision of clerks and customers. It is nevertheless desirable for the reasons mentioned in connection with Fig. 327.

Fig. 329 is an example of artistic and efficient lighting in the city ticket office of the Chicago & Alton Railway at Chicago. The principal part of the useful lighting is accomplished by the four Meridian lamps at the corners of the ceiling fixtures. The distribution from these lamps which is shown in Fig. 29 is excellent for the purpose. Frosted art glass is used inside the fixture proper. The lamps provided inside of the fixtures are

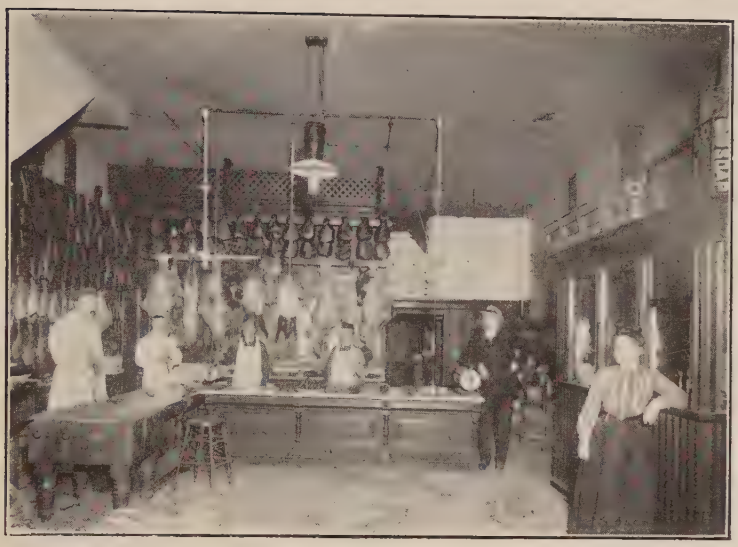


FIG. 328—Arc well placed in meat market.

FIG. 329—Artistic and efficient lighting in ticket office.

mainly decorative in their purpose, but could be made more useful by having reflectors placed over them. The lantern bracket lamps on the pillars are provided with ground glass which makes them at the same time pleasing and inoffensive to the eye. These brackets are of course principally decorative in purpose.

Fig. 330 shows the lighting arrangements of a grocery store where a large number of incandescent lamps have been installed for decorative and advertising purposes on the arches

FIG. 330—Decorative but inefficient store lighting.

along each side of the room. This is a case where frosted bulb lamps should be used to avoid the glare from so many lamps. In this case the electric lamps on the chandeliers cut very little figure in the total illumination as there are so many on the arches. The lamps on the arches would be more effective in illuminating the store if equipped with opal or prismatic reflectors, such as shown in Figs. 20, 32, and 34, although as a matter of fact there is such an abundance of them that when they are all lighted there is ample illumination. The same

useful illumination could be obtained with smaller candle power lamps by using reflectors.

Fig. 331 is a sample of how not to attempt to light a store. The lamps along the top of the medicine shelves are provided with a concentrating type of prismatic reflector, such as shown in Fig. 32 which is very efficient for certain purposes, but which

FIG. 331—Wrong place for reflectors.

is the very thing which should be avoided here for two reasons. In the first place, they reduce the amount of light which would shine down on to the shelves and throw the light clear across the store at an angle which delivers the light nowhere that it is needed. In the second place, the concentrated light from these reflectors is thrown directly in the faces of customers standing in the middle of the store looking toward the shelves, with the

result that the shelves will appear poorly illuminated because of the blinding effect of these lamps. At the upper left hand corner of the picture we see that there must be an ornamental chandelier high up near the ceiling provided with bare lamps. With the chandelier in such a location and the lamps pointed as they are, this is exactly the place to use reflectors. The proper thing to do in this case would be to take the reflectors off the lamps over the shelves and place them on the chandelier lamps where they would be effective in throwing light down in the store from the chandelier. Frosted bulb lamps without reflectors should

FIG. 332—The wrong reflectors for the place.

be used along the top of the shelves, if no change is made in the position or angle of the sockets. If the best results are wanted from these shelf lamps, short bracket fixtures which will permit the lamps being pointed down about 10 degrees from vertical should be used and the present reflectors retained. This will throw the maximum light on shelves and counters.

Fig. 332 shows an amusing mistake in the glassware equipment of a stationery store. This store has very artistic five lamp chandeliers with lamps pendant. On the chandelier arms are four lamps equipped with prismatic reflectors of a form which

concentrates most of the light immediately under the chandelier even more than shown in Fig. 31. Now, in a store of this kind with the chandeliers as far apart as they are here, a concentrating reflector is the very thing to be avoided since the light from each chandelier must cover a large area and must also light up the stock on the shelves. What is needed here is some kind of diffusing globe such as Fig. 83 or 81 or a type of prismatic reflector which will give a wider distribution of light, such as that

FIG. 333.—Bad mixture of colors.

shown in Figs. 37 and 43. If the reflector used here were of a type which exposed the lamp bulb, as in Fig. 44, a frosted bulb lamp would be decidedly advisable, even if the lamp were not over 16-candle-power.

Fig. 333 is a picture of a Chicago lunch room originally equipped with incandescent lamps which proved insufficient and were later supplemented by arc lamps. The arc lamps are well placed for the lighting of the main floor and balcony. The mixture of arc and incandescent lamps or in fact, the mixture

of any two different illuminants does not usually give pleasing results The effect is usually to make the smaller, yellower lighting units look sickly and weak. Thus incandescent lamps in the presence of arc lamps look yellow and ineffective although if the arc lamps were removed, thus removing the contrast of color, the incandescents would be very pleasing. The incandescents might have given better results if those along the gallery had been equipped with opal or prismatic reflectors.

Fig. 334 shows some of the most remarkable electric lighting

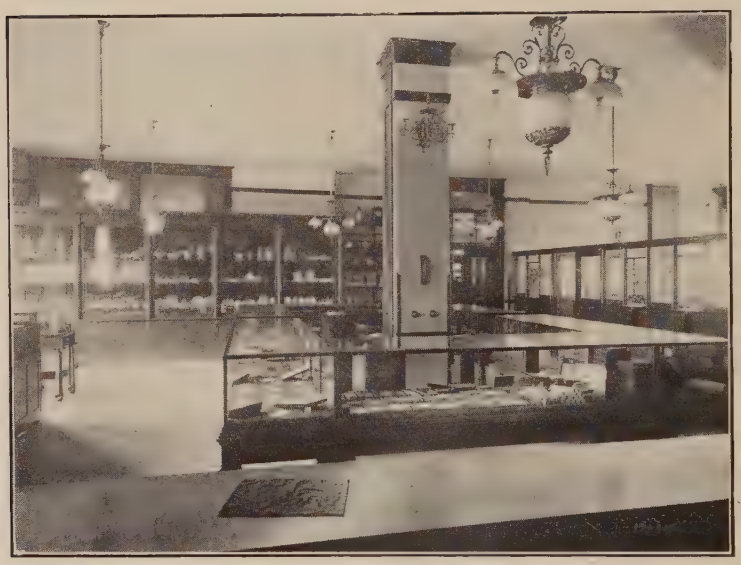


FIG. 334.—Absurd fixtures.

fixtures ever put in a store. The opal dome reflectors on the arms of the chandeliers are placed so high that the entire lamp is exposed and the effect is ridiculous, to say nothing of the fact that the value of these opal domes as reflectors is thus largely lost. Opal dome reflectors (see Fig. 21)properly placed on these chandeliers would be very effective, especially if frosted bulb lamps were used. The opal globes on the middle of the chandeliers must be regarded as mainly ornamental since they absorb probably about 40 per cent. of the light and in this case the top and bottom fittings prevent very much of the useful light that

remains from escaping. The bracket lamps on the pillar placed upright are also very ineffective since a large portion of their light is thrown to the ceiling. Pendant bracket lamps would have given considerably better results. Ground glass rather than opal globes should be used on them since opal wastes so much light and unless very dense, does not give a pleasing effect.

Fig. 335 shows an arrangement of chandeliers for lighting a store which is very pleasing if employed with ground glass globes on the chandeliers, but decidedly otherwise if opaline globes are employed

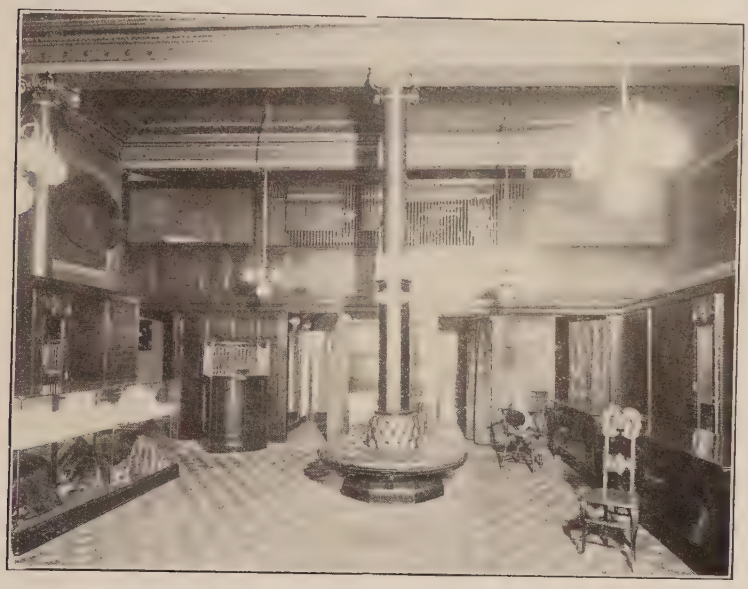


FIG. 335.—Fur store.

which allow the lamp filaments to show through with a sickly red color. With large enclosing globes of this kind it is always advisable to use pendant lamps as shown because of the chances that the globe holders will sag in time, if the lamps are placed at an angle. The arrangement shown in Fig. 335 is not especially efficient because plain diffusing globes of this kind do not have the power of directing the light downward. A more efficient arrangement would be to equip this type of fixture with frosted bulb lamps and prismatic reflectors giving a distribution such as in Figs. 29, 37, or 45; or globes such as shown in Figs. 81 or 89.

With the latter lamps should be placed low in the globe so as to give a wide distribution.

Fig. 336 shows the lighting arrangements in a builders hardware salesroom. The chandeliers have lamps pointed at an angle and equipped with opal bell reflectors such as in Fig. 24. Since these reflectors give their maximum candle-power at an angle of about 35 degrees below the horizontal, it is evident that an unnecessary amount of light is being thrown to the walls above the show cases. These lamps should be pointed straight down and

FIG. 336.—Hardware store.

frosted bulbs should be used, since so much of the lamp is exposed.

Fig. 337 shows the lighting arrangements of a picture frame salesroom in which it is important to have plenty of light on the high side walls because of the goods on display there. For this reason, the arrangement shown is fairly good as far as the lighting by incandescent lamps is concerned. Bare frosted incandescent lamps are arranged around the ceiling far enough back from the walls so that they do not interfere with the vision of persons looking up at the samples along the high side walls. These

lamps would be even more effective if placed in reflectors giving a light distribution such as in Fig. 29 or 43, as they would then throw almost as much light sideways and considerably more down than if bare.

Fig. 338 shows a very inefficient arrangement for jewelry store lighting. Above the counters are clusters of three bare incandescent lamps which are not only atrocious in appearance, but offensive and injurious to the eyesight. High up near the

FIG. 337.—Picture frame store.

ceiling are rows of incandescent lamps which would be very effective for the general lighting of the store if only they were equipped with the proper opal or prismatic glass reflectors giving a distribution such as in Figs. 29, 31 or 33. They have, however, a type of bell glass shade which is worth little for directing the light downward. A concentrating type of reflector should be used in this location. By doing this and either omitting the three lamp clusters or changing them to downwardly pointed bracket lights equipped with deep reflectors which would throw

FIG. 338. Inefficient lighting in jewelry store.

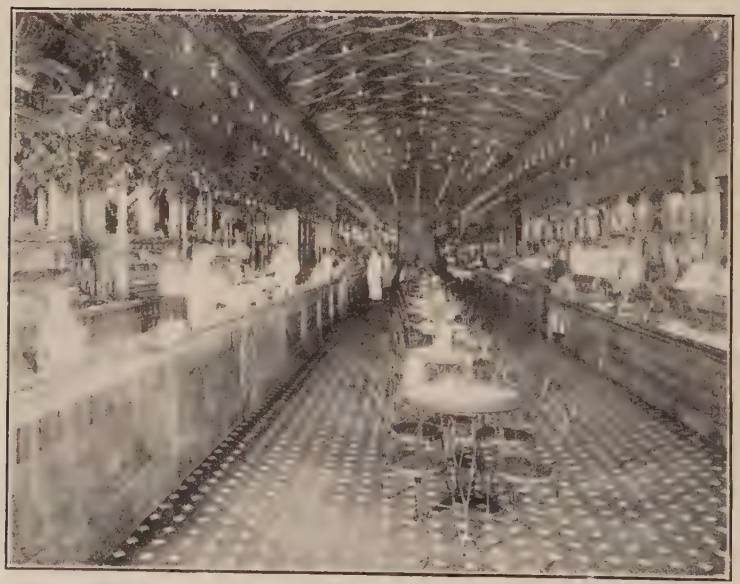


FIG. 339.—Decorative lighting in candy store.

the light down on the counter, the lighting of this store could be made both agreeable and efficient.

Fig. 339 shows the lighting of a candy store by means of a great number of studded ceiling lamps. The effect aimed at here is fully as much that of advertising as of useful illumination. A ceiling studded with so many lamps has a distinct advertising value. The main criticism to be offered is that in some of the sockets clear bulb lamps and in others frosted lamps have been employed which considerably detracts from the pleasing and artistic effect. In a case of this kind nothing but frosted bulb lamps should be used. If a merchant desired to light his store

FIG. 340.—Crude equipment in hat store.

by means of studded ceiling lighting of this kind without spending so much for advertising effect as in this case, fewer lamps could be used and by equipping these with opal or prismatic glass reflectors and frosted lamps, good distribution and high efficiency could be obtained. Concentrating reflectors should be used.

Fig. 340 shows a high-class hat store lighted with very cheap fixtures. These fixtures are clusters of incandescent lamps under metallic reflectors. Metallic reflectors have no place in this kind of work as they do not look well. They also darken the ceiling too much. The substitution at each outlet of a plain

three-light chandelier in place of the present clusters and placing on each chandelier three 32-candle-power frosted bulb lamps in opal or prismatic reflectors pointed about 15 degrees from vertical would improve appearances and give better efficiency than the present six-light clusters without increasing the cost of operation and without greatly increasing the first cost. Besides the bad appearance of the clusters in such surroundings, the glare received from them is likely to detract from the apparent general illumination by the blinding effect on the eye as

FIG. 341.—Handsome and efficient equipment in hat store.

previously explained. They deliver too much light horizontally as can be seen from Fig. 151.

Fig. 341 shows a very pleasing arrangement of fixtures in a store of a similar character to that shown in the previous illustration. Large Holophane spheres are suspended by chain fixtures. In such a case the lamps inside the spheres should be pointed down and equipped with reflectors. A similar scheme might be used with ground glass spheres. The best plan with spheres is usually to have but one lamp of high candle-

power with a large flat opal or prismatic reflector in the center of the sphere.

Fig. 342 shows some artistic lighting arrangements in the furniture department of a large store. This is a case where light is wanted in all directions both horizontally to light the galleries and downward, so that any type of diffusing globe is permissible. In this case a globe such as shown by Fig. 82 is used. The globe shown in Fig. 89 would be better yet.

Fig. 343 shows a handsome form of box fixture with art

Fig. 342.—Handsome fixtures in department store.

glass sides used in a Chicago cigar store. By equipping the lamps inside this fixture with reflectors a very good arrangement might be made. In addition to its artistic appearance, the strong point about this fixture is that it shades the eye from the direct rays of the light; only a diffused light passing through the art glass. The boxes are rather deep and narrow, but this is proper for covering a small area underneath the fixture as in this case. The same general plan of fixture can be used in some other places where the shading of the sources of light is required as, for example, in church lighting as already referred to.

Fig. 344 shows the lighting of a picture salesroom. The problem here is very similar to that of lighting a picture gallery of any kind. The general lighting is by means of hemispheres placed in the middle of the ceiling. The picture lighting is accomplished by incandescent lamps placed in a trough suspended from the ceiling as shown. In the lighting of individual pictures in homes and public buildings, a short trough reflector

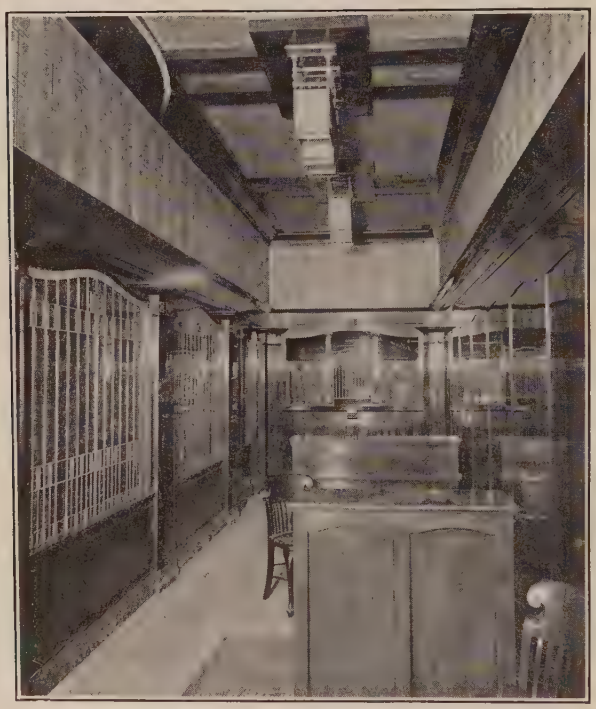


Fig. 343.—Box fixtures in cigar salesroom.

with outside finish corresponding to the finish of the picture frame can be mounted directly above the picture frame. It is advisable to use frosted bulb lamps in these trough reflectors to avoid streaks being cast on the picture which may interfere seriously with its appearance.

Fig. 345 shows a small store lighted by a gas arc lamp. The lamp is hung high so as not to interfere with seeing across the

FIG. 344.—Good lighting of picture salesroom.

FIG. 345.—Proper placing of gas arc lamp.

store. This is a good example of how a gas arc lamp should be used, except that an alabaster globe would be better.

Fig. 346 shows a hat store lighted with gas arcs equipped with alabaster globes. In a store of this length, where the arcs

FIG. 346.—Bad mixture of lights.

are placed low, the use of alabaster globes is to be highly commended. This is another example of where gas arcs are used effectively. Attention is called to the fact that an examination of this store will show that gas arcs, electric arc lamps, and electric incandescent lamps are used. This is highly repre-

hensible if all are lighted at the same time. We should be very careful at all times never to mix our color effects. Nothing in the lighting line is perhaps less attractive, than a place where we have the blue of an electric arc, the green of a mantle burner, and the yellow of an incandescent electric lamp.

Fig. 347 shows a millinery store equipped with bare mantle burners. The distribution of light is good, as will be seen by referring to the distribution curve of this combination shown in Fig. 112, but the glare is inexcusable. This should be compared with the store in Fig. 349, where opal chimneys are used

FIG. 347.—Too much glare.

and the distribution is not as good as in Fig. 347, but where, owing to the dense globes used, we have nearly perfect diffusion and a light which is soft and easy to see by.

Fig. 348 shows a candy store equipped with combination fixtures for gas and electricity. The gas lighting is excellent as far as diffusion is concerned, as Holophane shades are employed. The electric lamps have concentrating prismatic reflectors like those shown in Fig. 36. If frosted bulb lamps were employed to reduce the glare from the lamp filaments, this arrangement would be about the best one possible for store lighting with chandeliers of this kind.

FIG. 348.—Candy store with chandeliers.

FIG. 349.—Good equipment for gas chandeliers.

Fig. 349 shows a drug store lighted by gas mantle burners in opal chimneys. The opal chimneys, while absorbing considerable light, as seen in Chapter VI, nevertheless are desirable for reducing the intensity and softening the light so as to make it easier on the eyes. A four-lamp chandelier of this kind is more efficient than a four-lamp gas arc lamp because the burners do not interfere with each others light as much.

Fig. 350 illustrates the proper use of large Nernst lamps in lighting a large department store. Since the light distribution

FIG. 350.—Proper use of Nernst lamps.

from the Nernst lamp is mainly downward, as seen in Chapter IX, they should be placed high in store lighting to produce as even illumination as possible, as well as to avoid the blinding effect of lamps hung low. If small Nernst lamps are used, they can be applied to advantage as are the incandescent lamps in Fig. 324.

The quantity of light or amount of electrical energy required in store lighting necessarily varies considerably according to the ideas of the merchant and his customers as to what constitutes

a well lighted store. The standard is usually higher in cities than in small towns. With the most efficient lighting arrangement possible, such as for example that shown in Fig. 324, it is not advisable to allow less than 0.5 watt per square foot of floor area, and it is usually best to allow considerably more.

FIG. 351.—Marshall Field & Co. store, Chicago.

Mr. W. D'A. Ryan gives the requirements for high class store lighting by arc lamps as 0.5 to 1 watts per square foot for hardware and shoe stores and 1 to 1.5 watts for department stores.

One of the departments of Marshall Field & Company's retail store at Chicago, Fig. 351, has been the subject of careful

study by several engineers. This was equipped with incandescent lamps studded over the ceiling so as to give a fairly even light distribution. The lamps used were the Gem, graphitized carbon filament, high efficiency lamps. The reflectors were "inverted bowls" of prismatic glass, deep enough to cover and shade the lamp filaments from the eyes of persons looking the length of the store. Their shape and light distribution were similar to Figs. 37 and 38, except that the reflectors were necessarily larger to fit the large lamps and also gave a slightly larger proportion of their light directly downward. Each ceiling panel contained four lamps, of the 125-watt size and one of 187 watts. Lamps were, of course, pointed straight down. The power required for each panel was therefore 687 watts. The size of each panel was 21 by 22 feet and the ceiling height 15 feet. The watts per square foot were about 1.5. Ceilings and pillars were white and carpets and counters dark finish. It was found by various tests that the illumination in foot candles at the counters averaged about 3. This is brilliant illumination at a very reasonable expenditure.

CHAPTER XXVII.

SHOW WINDOW LIGHTING.

Some store windows are lighted to display the goods and others are lighted simply to attract attention to the place without regard to what there may be on display there. For example, in the highest class dry-goods stores the handsome display of goods in the show windows is in itself the best advertisement the store can offer. In other cases there may be nothing especially attractive to display in the window so that the main thing is to provide light of sufficient quantity and kind to attract attention to the place. In the latter case, the lighting can be considered as purely decorative; in the former case it is strictly utilitarian. In many windows these two are combined.

A common mistake in lighting show windows is to place a border of bare lamps entirely around the window with perhaps a lot of other lamps interspersed with the goods in the window. The effect of this is to practically prevent a person who is across the street from getting a very good idea of the goods on display in the window because of the blinding effect of the exposed lamps. We know from what has been said previously in regard to light and the eye that it is impossible to look past a source of bright light and clearly distinguish objects in the vicinity because the pupil of the eye automatically contracts in self-defense in the presence of such bright light.

Fig. 352 gives a good idea of the way a show window lighted with a border of incandescent lamps appears to a person across the street. It is impossible to see what is around the edges of the window, while the goods in the center are barely distinguishable.

In striking contrast to this is Fig. 353 which illustrates a show window lighted from above by concealed lamps. In this everything on display is brought out to the best advantage. For the lighting of such windows as shown in Fig. 354 several kinds of reflectors

FIG. 352.—Blinding effect of border window lights.

FIG. 353.—Window lighted to display goods.

may be used. The most common reflector is trough shaped such as in Fig. 63 with either glass mirror or metal reflecting surface. These trough shaped reflectors give good results with deep windows; that is, windows which extend far back from the street in proportion to their height. In the great majority of windows which are high and shallow cone shaped reflectors over each lamp which concentrate the light over a narrow angle as in Figs. 35, 53, 55, and 70 would give far better results than trough reflectors. Whatever reflector is used, it should in the highest class of stores be well concealed from the ordinary passer-by and care should be taken to have it pointed in a direction which will throw

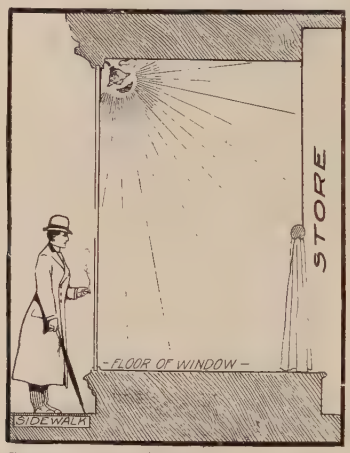


FIG. 354.—Proper placing of conical window reflector.

the light on the goods to best advantage. It is common to see reflectors mounted at angles which do not give the best results.

Fig. 354 shows the cross section of a show window indicating the proper position for lamps when placed in cone shaped reflectors for show window lighting. An opaque black band or its equivalent can be placed across the top of the window to hide the lamps from the street, or can be omitted if it is desired to expose this row of lamps to attract attention. In the latter case, an opaque reflector would not be used, of course. Where the reflectors are out of sight as in most of the high-class show window lighting their appearance need not be considered. The only questions to be decided in selecting reflectors for these places are questions of

durability and efficiency. Cone-shaped, opal and polished or enameled metal reflectors may be considered as out of the race for this work because of their comparative inefficiency. The choice of cone shaped reflectors will lie, therefore, between mirror and prismatic glass. Prismatic glass when used alone without any covering will not concentrate as much light for show window purposes as good mirror reflectors. By placing white cardboard or any other good reflecting surface over concentrating prismatic reflectors they can be made to give a performance very similar

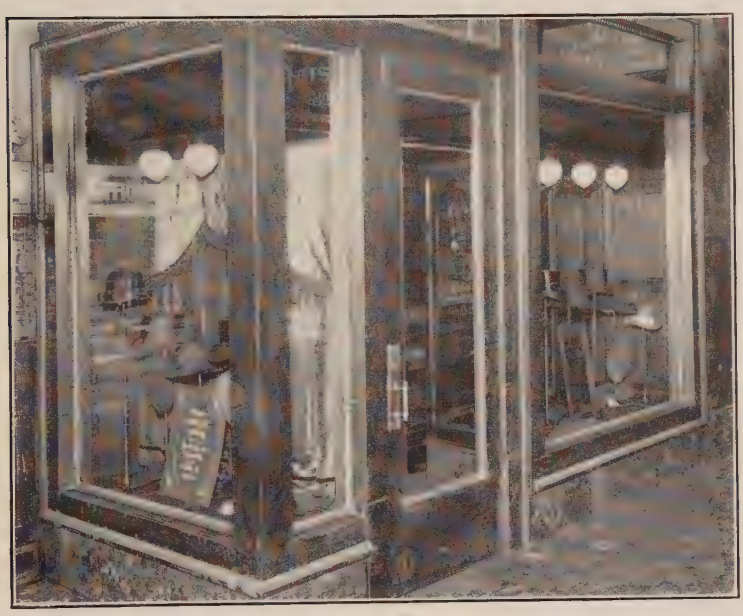


FIG. 355.—Combined useful and decorative window lighting.

to the best forms of mirror reflectors. Mirror surfaces are subject to depreciation with heat, age, and handling, although there is considerable difference in mirrors in this respect. Reflectors in the tops of show windows get very hot. Prismatic reflectors of course do not depreciate with heat. Their cardboard covers will have to be renewed occasionally on account of dirt.

It is frequently thought desirable by merchants to combine the useful illumination of a show window with a certain amount of display or decorative effect from the lamps themselves. This

can be done easily by placing the lamps near the top of the windows in handsome globes and fixtures designed to direct the light downward. Fig. 355 is an example of this. The globe used gives a light distribution similar to that in Fig. 78. Sometimes the visible decorative lighting is supplemented by concealed lighting from above for better lighting the goods.

Fig. 356 shows a window in which the principal object is to produce a large display of light rather than to illuminate a lot of goods. So much light is here used that the goods are well illuminated in spite of the fact that some of the light is so low as

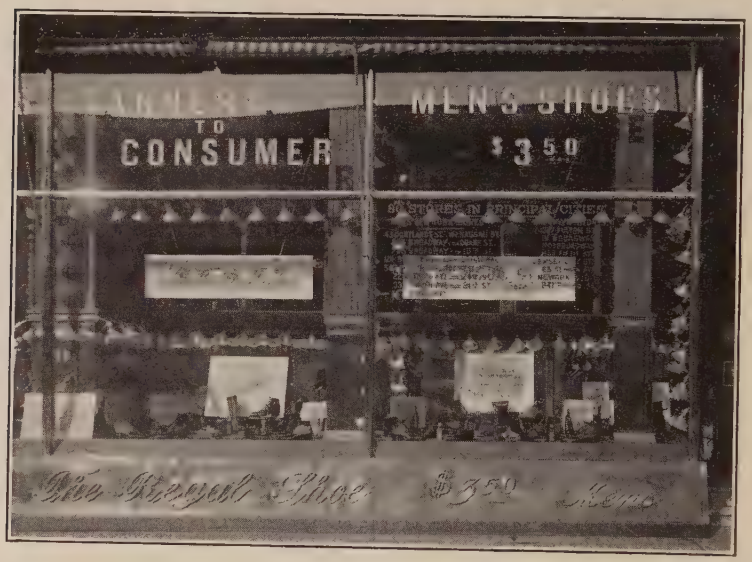


FIG. 356.—A display of lights.

to interfere with this result. A concentrating type of prismatic reflector is used

Fig. 357 shows another method of lighting a show window which, if properly designed, would combine the decorative and goods display features in one. As it is, it is neither effective nor handsome. The mirror reflectors placed in the top of the window for lighting the goods, although very efficient, are not handsome enough to be exposed. The lamps around the side of the window are not provided with effective glass reflectors to throw light on to the goods, although handsome reflectors for

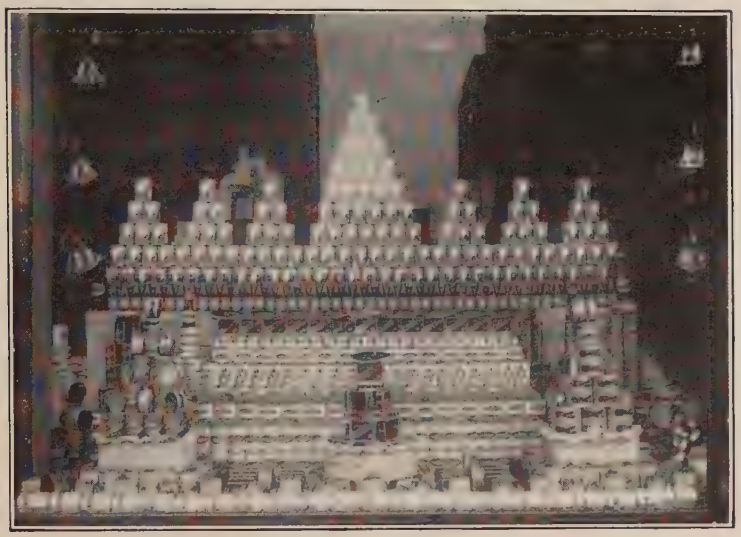


FIG. 357. A window easily improved.

FIG. 358.—Gas lighted window.

this purpose could easily be obtained, such as in Figs. 20, 32, 34, 36 and many others.

Fig. 358 shows the lighting of a window by gas where it is desired not only to throw the light directly down, illuminating the pictures at the bottom, but also to throw considerable light sideways as well. As the lamps are directly in the field of view

Fig. 359.—Decorative and useful window lighting.

of the passer-by, it is absolutely necessary to use diffusing globes. As it is necessary also to get a strong light downward, Holophane Class *A* shades are used (see Fig. 120), which fairly well accomplish the purpose. If the height of the ceiling were sufficient, this window could be much better lighted by placing the lights high enough to be practically out of the field of vision and using powerful reflectors to throw the light down.

Fig. 359 shows the window of a hat store where the main illumination is furnished by electric lamps hidden in trough reflectors, which are not visible in the picture. In order, however, to assist in attracting the passer-by, lamps are placed in large diffusing globes, which while adding little to the illumination of the goods below, nevertheless serve to attract attention.

For a very small store in a country town a very simple but effective combination window and display light can be obtained by hanging in sight near the top of the window a frosted bulb lamp of 32 candle-power or larger in a concentrating prismatic reflector, such as in Figs. 30, 34, 36 or 47 or many others. The use of a frosted bulb lamp is here important to make the source of light look large as well as for general better appearance.

CHAPTER XXVIII.

SHOP AND FACTORY LIGHTING.

It is coming to be recognized more and more that good artificial lighting in a shop or factory where night work is done has an important influence on the output. There is no better way to increase the output of a factory during the hours of darkness than by providing good general lighting. If the conditions as far as diffusion of light are concerned are made as near daylight as possible, daylight results in output can be obtained.

The most common method of shop and factory lighting when electric lighting was first introduced was to either place a few big arc lamps at infrequent intervals or to light by means of bare incandescent lamps hung promiscuously around the benches and machine tools. It is hard to say which of these methods is the most unsatisfactory as both are very poor. The most common method to-day is probably to provide for the general lighting by means of arc lamps and also to have incandescent lamps on flexible cords at each bench and machine tool. The most common mistake is that of failing to provide proper reflectors on these incandescent lamps. Metal reflectors as in Fig. 360 are usually advisable because of the danger of breakage. Tin cones (Fig. 50) painted with aluminum paint or aluminum cones (Fig. 52) or parabolic reflectors with frosted aluminum finish (Fig. 59) are good for this. Painted reflectors can be repainted when dirty and the frosted aluminum finish can be restored with sand paper. Such reflectors are important not only on account of the great increase in intensity of light on the work obtained by their use, but even more because they shade the light from the eye of the workman so that he is not blinded by it and can see what he is doing. In case the lamps are used around machinery and are enclosed in lamp guards to prevent their breakage, it is not practicable to use the ordinary form of reflector. In such cases a piece of asbestos paper slipped

over half the lamp inside the guard or a piece of tin covering half the lamp is advisable. Frequently these lamps are used around machinery where the eye of the workman must be close to the lamp and he is working under a severe handicap if he is obliged to look at a bright light as he usually is.

After all, the problem of factory lighting is in many respects similar to that of lighting large offices. It may be done by means of a number of small units, such as incandescent lamps placed over or near the machines and benches to be lighted or it may be done by large units such as arcs or vapor tube lamps in sufficient

FIG. 360.—Shop with metal cone reflectors—incandescent lamps.

numbers to flood the whole place with light. The latter method approaches nearest to daylight working conditions and so gives the workers the greatest freedom and permits them to do the most work. For this reason it is becoming popular.

Machine shop work requires an extremely good light, as good in fact as drafting where an intensity of from five to ten foot candles is none too much. It is also important that there be few sharp shadows around tools or work and that the glisten and glare from tools and machinery be a minimum. For this reason the light giving surfaces of the lamps should be as large as possible and if conditions permit it the walls and ceiling should

be kept white. Clear globe arc lamps would be the very worst thing to use. The lamps best suited to factory lighting in view of these requirements are either mercury vapor tube lamps where the light comes from long tubes, or arc lamps with concentric diffusers or large opal globes and large reflectors, where the light comes from a large globe and reflector surface rather than from a small point. With any of these lamps which have large light giving surfaces there is an absence of sharp shadows as well as an absence of glisten and glare from the material that

FIG. 361.—Mercury vapor lamps in thread factory.

is being worked upon. In brief, the lighting is more nearly in character that obtained from the windows by daylight, although of course the shadows and glisten referred to are not as effectually avoided as they are by daylight. The ghastly color of persons under the mercury vapor light is usually objected to at first by those working under it, but this feature is soon forgotten. When colors must be judged the mercury vapor lamp cannot of course be used.

Another way to accomplish well diffused lighting would be to

place large incandescent or small Nernst lamps at frequent intervals in proper reflectors about 10 to 15 feet above the floor, as in the case of some of the stores cited in Chapter XXVI. This plan is seldom resorted to because of the high first cost of so many outlets or because of ceiling obstructions.

Where most of the lighting of a shop is to be done by means of arc or mercury vapor lamps placed high, care must be taken to place the lamps so that the workmen will not stand in their own light and so that the greatest light will be obtained where

FIG. 362.—Mercury vapor lamps in belting factory.

detailed work is being done. For example, in a great many factories benches and small machines tools are placed around near the walls in order to obtain light from the windows during the day. The proper place for the lamps is, therefore, around the edges of the room rather than in the center as they are frequently placed. While this may appear like wasting too much light on the side walls and robbing the center of the shop, it usually gives the workmen better light than placing the lamps in the center so that they are a long distance from the benches and the workmen stand in their own light. If the walls are

whitewashed as they usually are in the progressive factory, a large per cent. of the light thrown toward the wall will be reflected and not lost.

Fig. 361 shows a cotton thread factory w'th mercury vapor lamps. The old method of lighting by bare gas jets is also seen. The vapor lamps are located over the machines and adjacent lamps are relied upon to light under and around the machines.

Fig. 362 shows a leather belting factory with vapor tube lamps placed over the machines. In both of these factories reflection from the ceiling should play an important part. Where traveling cranes are employed the lamps should be placed above the crane and provided with reflectors.

For shop lighting about the same amount of light is required as in drafting room lighting. The power required should be from one to two watts per square foot with mercury vapor lamps and 2.5 to 5 watts with common carbon arcs. These figures apply only to those portions where machine or bench work is being done, which requires the best light. The average for a whole shop or factory will rarely need to be over half the foregoing figures.

CHAPTER XXIX.

MISCELLANEOUS EXAMPLES OF LIGHTING.

Billiard Room Lighting.

A brief discussion of billiard room lighting was taken up in Chapter XVI on Residence Lighting and the requirements for that class of lighting were there stated together with the proper height and distance apart of lamps for different sizes of tables.

The reflector used on the table in the residence referred to in that chapter was a deep prismatic reflector giving a distribution of light very similar to that shown in Fig. 37. With such a reflector (which gives a very wide distribution and at the same time covers the lamp, so that a player will not receive the glare from the lamps when stooping over the table to play) it is good practice to place the lamps lower than if some other forms of reflector were used. For example, in Fig. 363 the billiard table lamps are arranged on a chandelier in approximately the same way as indicated in the chapter on Residence Lighting, but the lamps are placed about 5.5 feet above the bed of the table. In Fig. 363 a reflector such as shown in Fig. 54 is used. From Fig. 53 it will be seen that this reflector gives a fairly concentrated distribution and that it can, therefore, be with advantage placed higher than one giving a distribution such as shown in Fig. 37. Attention is also called to the excellent provisions made for the general lighting of the room aside from the billiard tables in Fig. 363. This is a good example of the proper use of Holophane globes in contrast to the improper use so often made of them. On the chandelier in the foreground, the chandelier arms which have lamps pointed at an angle of about 45 degrees have concentrating globes giving a distribution of light such as shown in Fig. 78, this being the proper globe for use on a chandelier with sockets at an angle. On the bottom of this chandelier is a large ball giving a distribution at all angles below the horizontal such as in Fig. 82. Around the side walls are

brackets placed very high so as to be out of the line of vision of players and others and these brackets are equipped with the same globe as used on the chandelier arms. It is a mistake to equip sockets pointed at an angle of 45 degrees with Holophane stalactites giving a general distribution below the horizontal, as in Fig. 80, as it results in an unnecessary amount of light being thrown toward the ceiling.

Fig. 364 shows the method of lighting a very handsome billiard room, which method however is open to considerable improve-

FIG. 363.—Excellent billiard room lighting.

ment. Each billiard table is lighted with a row of four lamps in opal dome reflectors. The distribution of light from a smaller opal dome reflector can be seen in Fig. 21. The characteristic of the opal dome is that it gives considerably more light immediately under the lamp than at an angle of 30 degrees from the vertical. The result is that where lamps are placed close together as in this case with this reflector there will be a row of bright spots under the lamps which is objectionable in billiard table lighting, as a billiard table should be lighted evenly over its entire surface.

FIG. 364.—Defective billiard table lighting.

FIG. 365.—Very bad plan of billiard room lighting.

If opal dome reflectors are used in such a place, they should be equipped with frosted lamps to avoid the streaks which they cast. They should, furthermore, be arranged somewhat as shown in Fig. 363, rather than in a row close together over the middle of the table. In order to shade the players from the glare of the lamp filaments when playing, the lamps should be placed higher. They are only a little over three feet above the bed of the table in this case.

Fig. 365 is an example of how not to light a billiard room. Over each table is a row of three Gem high efficiency incandescent lamps in concentrating prismatic reflectors of the type shown in Fig. 47. The glaring defect of this arrangement is that the lamp is not shaded from the eyes of players and with so many lamps like this hung low in a room it seriously interferes with the comfort of everyone in the room. Large unshaded incandescent lamps like this, even though they may be provided with frosted bulbs should never be hung low, especially in a large room like this.

Barber Shops.

In a barber shop the important point is to have an abundance of light coming from a number of directions so as to avoid annoying shadows. In this case, large units of light, such as arc lamps and incandescent clusters are to be avoided in small barber shops because of their tendency to cast shadows. There should rather be a large number of small lighting units well distributed. As it is impossible to locate the lamps in a barber shop so that they will be out of the line of vision of all customers and barbers, they should be always provided with diffusing globes. Barber shops should always be finished in light tints to aid in the general diffusion of light and freedom from shadows. The large mirrors also assist in this.

Fig. 366 shows the lighting of a barber shop where these principles are well carried out. Here much of the light is obtained from lamps in ground glass balls between the mirrors. This is supplemented by light from lamps in ground glass balls on the ceiling fixtures. As these ceiling fixtures are so high, this would be a good place to employ prismatic reflecting balls of the type shown in Fig. 89 or a globe such as shown in Fig. 79, either of which would assist in directing the light downward. Still more light would be thrown down by using lamps in reflectors of the types

FIG. 366.—Good barber shop lighting by electricity.

FIG. 367.—Good barber shop lighting by gas.

shown in Figs. 30 or 44 with frosted bulb lamps but this would be undesirable except from motives of economy because the light would not be as well diffused and reduced in intensity as it is at present with the ground glass balls and lamps of low candle-power.

Fig. 367 shows a barber shop lighted with gas mantle burners in ground glass chimneys and fluted opal reflectors. This arrangement provides about as good diffusion and distribution as can be obtained with gas. Its chief objection is its looks.

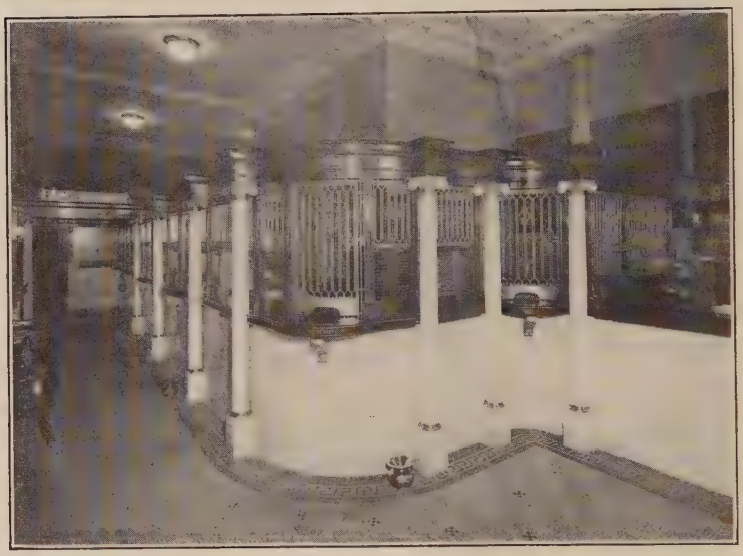


FIG. 368.—Bank lighting from hemispheres.

BANK LIGHTING.

The lighting of banks is very similar in its requirements to the lighting of large offices. There is usually the difference that more attention must be paid to appearances in banks than in offices. In recent years the general lighting of banks has been very largely done from lamps placed at the ceiling in globes or hemisheres, this lighting being frequently supplemented by lamps in globes on top of the partition behind which the bank employees work. The lighting of the desks in a bank is usually done by means of desk lamps placed just over the desks to be lighted. The desk lighting feature of a bank by means of such lamps in

itself introduces serious difficulties because a desk lamp properly placed to light one clerk's desk or table is not right for his neighbor who may be facing him. Taken all together, it is much better to provide sufficient general illumination, so that special desk lamps will not have to be used, thus doing away

FIG. 369.—General lighting in Milwaukee Public Service Building.

with all of these difficulties at one stroke. Over the teller's windows, nevertheless it is usually advisable to place a lamp in a concentrating reflector. The reflector shown in Fig. 57 is an excellent one for the purpose, because it is opaque and provided with a ground glass bottom.

The defects in most bank lighting arrangements as far as bookkeepers and clerks are concerned are well illustrated by the number of makeshifts one commonly sees employed about almost any bank to secure proper shading of desk lamps from the eyes.

Fig. 368 shows a bank in which the general lighting is accomplished by Holophane hemispheres on the ceiling. Such hemispheres should always, in a case of this kind, be equipped with a single lamp pointed straight down provided with a reflector as explained in Chapter VIII. A very inefficient modification of the plan used in Fig. 368 is frequently seen in banks where opal or opaline globes are placed on the ceiling without any means of directing the light downward.

Fig. 369 shows the method employed in the accounting department of The Milwaukee Electric Railway & Light Company and in fact, all over the Public Service building of that company. The plan here has been to provide such an abundance of general illumination that no special desk lighting is necessary. One-lamp pendants are placed at frequent intervals, these pendants being equipped with Gem graphitized carbon filament lamps of the types shown in Figs. 41 to 48. This is undoubtedly a very efficient way of providing general illumination free from annoying shadows and glare from papers. It also provides for lighting one corner of a room thoroughly when it is not necessary to light other portions, which cannot be said of schemes where very large lighting units are employed.

Hospitals.

It is easy to lay down what should be the theoretical ideal specifications for the lighting of a hospital room, be it large or small. There should be plenty of light for the nurses to work by and the light should not shine in the eyes of patients. How difficult it is to live up to such specifications can be seen from a brief study of Fig. 370 which represents the average conditions in a large hospital room. The lamps placed down the center on chandeliers must necessarily shine in the eyes of patients in the beds and the same is true of the lamps on the brackets. It would seem that here, if anywhere, was a desirable place for some scheme of indirect lighting for the general illumination; this to be supplemented by lamps in opaque or nearly opaque reflectors for special purposes near each bed. In the case shown

in Fig. 370 the gas mantle burners have been rendered as nearly inoffensive as possible by the use of Holophane globes which reduce the intensity of the light, so that it is not as injurious to the eye as if coming through a clear chimney. It is, nevertheless, trying for patients to face it for any length of time. The problem of hospital lighting has never been worked out with thorough satisfaction in practice and there is room for considerable improvement along the lines indicated, namely, the provision of very mild general lighting, the sources of light preferably being hidden, and the provision of special concentrated lighting at

FIG. 370.—Hospital lighting.

each bed for temporary use of doctors and nurses. Such concentrated lighting would probably have to be done with some kind of adjustable wall bracket. Adjustable wall brackets in such locations would be, to a certain extent, objectionable because of the chances that they would be misused and that light would be left directed in the eyes of patients. This possibility of misuse must also be borne in mind in the design of such lighting and in fact of all lighting where adjustable fixtures are used.

APPENDIX.

The following are the manufacturers' names and numbers, or trade designations of the reflectors, shades and globes upon which tests are given in the body of the book. In some cases where the articles are staple trade products manufactured by a number of companies, the dimensions are given. Where, however, the article tested is made by one company only, its catalogue number has been considered a sufficiently definite description. In this list, a large number of the tests given in the body of the book are not included for the reason that sufficient description and illustration of the article tested is found in connection with the test. In some cases, the name of the manufacturer is not known:

Fig. 16.—General Electric Co., 16 candle-power oval anchored filament lamp.

Fig. 17.—Same as Fig. 16, but frosted by acid etching process.

Fig. 18.—Tantalum lamp made by Siemens & Halske in Germany.

Fig. 19.—Fluted opal cone reflector. Staple trade article. $6\frac{7}{8}$ inches diameter by $3\frac{7}{8}$ inches high.

Fig. 21.—Opal dome reflector. Staple trade article. $7\frac{1}{4}$ inches diameter by $3\frac{7}{8}$ inches high.

Fig. 23.—Opal bell reflector. Staple trade article. 5 inches diameter by $2\frac{1}{2}$ inches high. Held by socket bushing. No shade holder.

Fig. 25.—Green plated opal desk shade. Staple trade article. 7 inches diameter by $4\frac{1}{2}$ inches high.

Fig. 27.—Flat opal reflector. Staple trade article. 10 inches diameter.

Fig. 29.—120 watt meridian lamp, General Electric Co., with Holophane Glass Co. reflector, 2575.

Fig. 31.—Prismatic reflector. Holophane Glass Co., 2621.

Fig. 33.—Prismatic reflector. Holophane Glass Co., 2301.

Fig. 35.—Prismatic reflector. Holophane Glass Co., 2651.

Fig. 37.—Prismatic reflector. Holophane Glass Co., 7381.

Fig. 39.—Prismatic reflector. Holophane Glass Co., 2510.

Fig. 41.—General Electric Co. "G. E. M." High efficiency, 125 watt clear bulb lamp.

Fig. 42.—Same as Fig. 41, but with frosted tip.

Fig. 43.—Same as Fig. 41, with Holophane Glass Co. reflector, 6052.

Fig. 45.—Same as Fig. 42, with Holophane Glass Co. reflector, 6052.

Fig. 46.—Same as Fig. 41, with Holophane Glass Co. reflector, 6050.

Fig. 48.—Same as Fig. 42, with Holophane Glass Co. reflector, 6050.

Fig. 49.—Metal cone reflector painted white inside. 8 inches diameter by $3\frac{1}{2}$ inches high.

Fig. 51.—Aluminum cone reflector, frosted finish inside. $6\frac{3}{4}$ inches diameter by $3\frac{3}{4}$ inches high.

Fig. 53.—National X-Ray Reflector Co., 696. $9\frac{3}{4}$ inches diameter by 6 inches high.
Fig. 55.—Same as Fig. 53, with 32 candle power lamp.
Fig. 56.—McCreary desk shade. 7 inches diameter by $5\frac{1}{2}$ inches high.
Fig. 58.—Parabolic aluminum reflector. $6\frac{1}{4}$ inches diameter by 3 inches high. Frosted inside.
Fig. 60.—Cylindrical desk reflector. $4\frac{1}{2}$ inches diameter by $6\frac{1}{4}$ inches long.
Fig. 62.—Window trough reflector made up with glass plate mirrors. Width $6\frac{3}{4}$ inches; height $3\frac{1}{2}$ inches.
Fig. 64.—Flat metal reflector, painted white inside. 8 inches diameter.
Fig. 66.—National X-Ray Reflector Co., 695. 10 inches diameter.
Fig. 70.—Tin cone with glass plate mirrors inside. Standard trade article. 10 inches diameter.
Fig. 72.—Same as Fig. 70, with 32 candle-power lamp.
Fig. 73.—Sand blasted dome, similar to Fig. 21, but shallower. Diameter 7 inches, height $3\frac{1}{4}$ inches.
Fig. 74.—Sand blasted ball. Staple trade article.
Fig. 78.—Holophane Glass Co., 3363.
Fig. 80.—Holophane Glass Co., 3358.
Fig. 82.—Holophane Glass Co., 3154.
Fig. 84.—Holophane Glass Co., 3105.
Fig. 88.—Holophane Glass Co., 9137.
Fig. 94.—Holophane Glass Co., 2450.
Fig. 96.—Holophane Glass Co., 2805.
Fig. 98.—Holophane Glass Co., 1385.
Fig. 100.—Holophane Glass Co., 245.
Fig. 107.—Welsbach Co., shade, 1687.
Fig. 109.—Holophane Glass Co., 4401.
Fig. 111.—Welsbach Co., No. 60 burner, No. 197 mantle, 8 inch clear chimney.
Fig. 112.—Same as Fig. 111, but with Welsbach Co. fluted opal reflector, No. 74.
Fig. 114.—Welsbach Co., Q chimney, No. 66 burner, No. 4197 mantle, No. 302 Q globe.
Fig. 116.—Welsbach Co., No. 60 burner, No. 197 mantle, No. 82 chimney.
Fig. 118.—Welsbach Co., No. 60 burner, No. 197 mantle, No. 0472 chimney.
Fig. 120.—Welsbach Co., No. 61 burner, No. 197 mantle, Fig. 310 chimney, and Holophane Glass Co., shade, 3321.
Fig. 122.—Welsbach Co., No. 66 burner, No. 197 mantle, and Holophane Glass Co., shade, 2811.
Fig. 124.—Same as Fig. 122, except with Holophane Glass Co., shade, 2711.
Fig. 126.—Welsbach Co., No. 60 burner, No. 197 mantle, 8 inch clear chimney, No. 10 dome and No. 43 Bobesche.
Fig. 128.—Same as Fig. 126, but with Welsbach Co. dome 1036 and No. 43 Bobesche.
Fig. 129.—Welsbach Co., No. 60 burner, No. 197 mantle, 8 inch clear

chimney, 10-inch green plated opal dome, and Holophane Glass Co., Bobesche, 1386.

Fig. 130.—Reflex burner and reflex mantle with clear air hole chimney No. 317, Welsbach Co.

Fig. 131.—Same as Fig. 130, with 5 inch French rough ball.

Fig. 133.—Same as Fig. 130, with flat opal reflector, 503.

Fig. 135.—Same as Fig. 130, but with opal cone reflector, 502.

Fig. 137.—Same as Fig. 130, but with Holophane Glass Co. reflector, 2333.

Fig. 141.—Acetylene gas flame in Welsbach Co. shade, 1687.

Fig. 142.—Opal shade, Staple trade article. $7\frac{1}{4}$ inches diameter by $3\frac{7}{8}$ inches high.

Fig. 144.—Holophane Glass Co., 2807.

Fig. 145.—Benjamin Electric Mfg. Co. "arc burst," D-47.

Fig. 147.—Holophane Glass Co., Holophane "Reflecting Arc."

Fig. 149.—Three-light Benjamin cluster with Holophane Glass Co. reflectors, 2631.

Fig. 155.—Holophane Glass Co., 2522.

Fig. 159.—Holophane Glass Co. hemisphere, 701.

Fig. 169.—Holophane Glass Co., 1201.

Fig. 172.—Three-light cluster with Holophane Glass Co. reflectors, 2535.

Fig. 177.—Holophane Glass Co., 3165.

Fig. 191.—Excello Arc Lamp Co., 8 ampere arc.

Fig. 192.—Welsbach four-light gas arc. Clear globe.

Fig. 193.—Welsbach Co., four-light gas arc, clear globe and flat porcelain reflector.

Fig. 195.—Welsbach Co., four-light gas arc, alabaster globe. No reflector.

Fig. 197.—Humphrey four-light gas arc, clear globe, no reflector.

Fig. 199.—Humphrey four-light gas arc, alabaster globe, no reflector.

Fig. 201.—Cooper-Hewitt Electric Co., mercury vapor lamp.

INDEX.

PAGE.

Acetylene Gas ..... 96 to 100
Aluminum Reflectors 48, 51, 215, 219
Arc Lamps, Electric ..... 120 to 127
  Alternating arc tests 125, 126
  Difficulties of testing 120
  Direct current tests ..... 120 to 123
  Effect of small carbons 123
  Efficiency of 143
  Flaming arc tests ..... 127 to 143
Arc Lamps, Gas ..... 128 to 133
  Consumption of 132
  Efficiency of ..... 132 to 144
  Horizontal distribution of 128, 129
  Mean spherical candle-power of 132
  Vertical distribution of ..... 130 to 132
Asbestos Reflectors for Bowls 108
  Gaskets for closed globes 50, 62, 74
Bank Lighting ..... 342 to 344
Banquet Room Lighting. See Dining-Room Lighting, Hotels.
Barber Shop Lighting ..... 340 to 342
Basement Lighting 204
Bath-Room Lighting 203, 213
Bed-Room Lighting ..... 182 to 196, 213
Billiard-Room Lighting ..... 212, 337 to 340
Blinding Effects of Unshaded Lamps 1, 2
Bowls, Beaded 110
  Ground Glass 100, 110, 137
  Holophane 107, 112, 157
  Opaline 112
  Sand blasted 106, 110, 137
  Reflectors for 108
Calculation of Illumination ..... 13 to 24, 226, 229, 242, 299, 323
Candle-power, Mean Spherical, of
  Acetylene gas flame 99
  Gas, open flame 79
  Gas, mantle burner 82

PAGE.

Candle-power, Mean Spherical, of
Gas, inverted burner 91
Gas arcs 132
Gem electric incandescent 42
Incandescent electric, common 26, 27
Nernst lamp 115
Tantalum incandescent electric 29
Candle-power, mean spherical, definition of 23
Candle-power, mean spherical, comparisons of 143, 144
Car lighting ..... 288 to 292
Ceiling vs. Chandelier Lighting 138
Chandelier vs. Ceiling Lighting 138
Church Lighting ..... 268 to 279
Club Lighting, Dining-Room 238
See also Dining Rooms, Lighting, Hotels.
Clusters, Electric.
"Arc Burst" 101
Flat opal 102
Metal 104
Prismatic 101, 102, 105
Color of Illuminants 145, 297, 298, 299
Comparison of Illuminants ..... 142 to 146
Concentric Diffusers 225
Contrasts, Effect on the Eye 11
Corridor Lighting, Clusters for 102
(See also Hall Lighting.)
Critical Angle for Shading Eyes 227
Demonstration-Room Tests ..... 136 to 141
Depot Lighting ..... 241 to 244
Design of House Lighting 207
Desk Lighting ..... 215 to 226
Reflectors for ..... 37, 41, 49 to 53, 138
Desk Portables ..... 217 to 221
Dining Car Lighting 290
Dining-Room Lighting.
Disks, to keep out dirt 50, 62, 74
Hotels ..... 178, 232 to 240
Residences ..... 172 to 182
Drafting-Room Lighting ..... 224 to 226
Dresser Lighting ..... 182, 187 to 193
Efficiency of Light Sources.
Electric 143
Gas 144
Electrical Testing Laboratories VI
Eye and Light ..... 1, 2, 9 to 12
Factory Lighting ..... 134, 332 to 336

PAGE.
Fixtures, Design ..... 148, 149, 276 to 279
Church lighting design ..... 276 to 279
Schedule 207
Specifications 207
Flaming Arcs 127, 143
Flat Flame Gas Tests ..... 79 to 82
Flickering Lights 9
Foot Candles.
Amounts required ..... 22 to 24
Definition of 14
Frosted Lamps, Advantages of 28
Life of ..... 73 to 75
Photometric curve of 27
Use with reflectors 34, 41
Frosted Reflectors 58, 139
Gas Burners, Cluster ..... 128 to 133
Individual ..... 76 to 95
Gas, Acetylene ..... 96 to 100
Effect of pressure variations 76
Efficiency of different burners 144
Open flame ..... 79 to 82
Tips 77
Gas Globes and Shades.
Fancy glass 84
Ground glass 84
Holophane ..... 86 to 90
Opal Q chimney 83
Gas Reflectors 83, 88, 93, 130
Gaskets 50, 62, 74
Gem Lamps ..... 41 to 44
Efficiency of 143
Globes, Enclosing Electric ..... 59 to 67
Gas ..... 76 to 95
Open electric ..... 67 to 72
Grill-Room Lighting 233
Hall Lighting, Clusters for 102
Hotels 256
Office buildings ..... 255 to 261
Public halls ..... 227 to 231
Residence 203, 212, 213
Hemispheres, see Bowls.
Holophane Globes, Absorption of 61
Acetylene globes 100
Bowls 107, 112, 137
Classes of 60
Cleaning of 61, 62
Dust tests 62, 88

PAGE.

Holophane Globes, Absorption of
Electric globes, closed....62 to 66, 138, 140
Electric globes, open....69 to 72, 138
Hemispheres....107, 112, 137
Mantle burner globes....86 to 90
Nernst globes.... 116
Open gas globes.... 81
Principles of.... 59, 60
Holophane Reflectors, see Prismatic Reflectors.
Horizontal Illumination.... 16
Hospital Lighting....344, 345
Hotel Lighting.
Bed-Rooms....189 to 196
Dining Rooms....178, 232 to 240
Halls.... 256
Lobbies, see Lobby Lighting.
Parlors....170 to 172
House Lighting....151 to 214
Design of....207 to 214
Illuminating Engineering Society.... V
Illumination Curves of.... 21
Horizontal.... 16
Normal.... 15
Vertical.... 22
Incandescent Electric Lamps....25 to 75
Light distribution of carbon filament lamp.... 26
Light distribution of carbon filament lamp, frosted.... 27
Light distribution of Gem lamp....41 to 44
Reflectors, shades and globes....25 to 75
Tantalum.... 28
Efficiency of.... 143
Incandescent Gas Burners....82 to 95, 128 to 133
Indirect Lighting, Hotels....250, 251
Railroad depot....241 to 244
Injurious Effects on the Eye of
Contrasts.... 11
Flickering light.... 9
Glare.... 10
Light from an Unusual Angle.... 10
Light in the field of vision.... 10
Streaks.... 11
Too little light.... 11
Too much light.... 11
Unsteady light.... 11
Inverse Squares, Law of.... 3, 14
Inverted Gas Burners....90 to 95
Efficiency of.... 143

PAGE.
Kitchen Lighting ..... 196 to 199, 213
Large vs. Small Lighting Units 295, 296
Laws of Light ..... 3 to 8
Library Lighting, Public Libraries ..... 280 to 287
Residence Libraries ..... 161 to 163
Light and the Eye ..... 1, 2, 9 to 12
Flickering 9
From an unusual angle 10
In the field of vision 10
Laws of ..... 3 to 8
Laws of inverse squares 3, 14
Nature of 3
Too little 11
Too much 11
Unsteady 9
Living-Room Lighting ..... 151 to 172, 212
Lobby Lighting ..... 244 to 254
Location of Lamps 2
Lodge-Room Lighting ..... 227 to 231
Mantle Burners, see Gas Burners.
McCreary Reflector 50
Mean Spherical Candle-Power, see Candle-Power.
Measurement of Light ..... 3 to 8
Mercury Vapor Lamps ..... 134 to 135
Efficiency of 145
Examples of ..... 225, 226, 334 to 336
Meridian Lamps 36
Metal Reflectors, Aluminum Cone 48
Parabolic 51, 215, 219
Cluster type 104
Cylindrical desk type 53, 215, 219
Flat enameled type 55
Tin cone enameled 46
Mirror Reflectors ..... 48 to 50, 54 to 58
Moore Tube Light 135
Mounting of Lamps in
Art glass domes 169, 173
Balls 114
Bowls 108
Table lamps 167
Nernst Lamps ..... 115 to 119
Advantages of 119
Correct placing of 118
Efficiency of 143
Efficiency of different sizes 117
Examples of use of ..... 239 to 244, 308, 321, 335
Normal Illumination 15

PAGE.
Office Building Lighting
Corridors ..... 255 to 261
Lobby 249, 252
Offices ..... 215 to 226
Opal Reflectors for
Clusters 102
Electric arc lamps 126
Gas, flat fluted 86
Gas, dome shape ..... 88 to 9[illegible]
Incandescent electric lamps.
Bell shape 32, 138
Cone shape 29, 34, 137
Dome shape 31, 139, 140
Flat 34
Mounted gas, flat 92
Cone 93
Open Flame Gas Tests ..... 79 to 82
Parlors, Lighting of ..... 151 to 172, 212
Photometric Curves ..... 25 to 135
Meaning of 13
Photometers ..... 3 to 5
Placing of lamps 2
See also Mounting of Lamps.
Porch Lighting ..... 199 to 203, 211
Portable Lamps 139, 152, 153, 158, 163, 166
Prismatic Reflectors.
Advantages of 35
Ball type 66
Bowl type 40, 138, 140
Cleaning of 289
Cluster type 101, 102, 105
Concentrating type ..... 37 to 39, 137 to 139
Desk type 41, 215, 216, 218
Gem type ..... 41 to 44
" Inverted bowl " type 40, 138, 140
Inverted gas 93
Meridian type 36
Wide distribution type 40, 138, 140
Public Hall Lighting ..... 227 to 231
Quantity of Light ..... 22 to 24, 226, 229, 251, 299, 323
Railroad, Car Lighting ..... 288 to 292
Depot lighting ..... 241 to 244
Reading Lamps. See Portable Lamps.
Reading-Room Lighting. See Library Lighting.
Reading Table Lighting ..... 161 to 163, 280 to 287
Reflection, Coefficients of 7, 21
Diffuse 6

PAGE.

Reflection, Coefficients of
Irregular 6
Regular 5
Total 8
Reflectors, Aluminum 48, 51, 215, 219
Frosted 58, 139
Holophane. See Prismatic Reflectors.
Metal. See Metal Reflectors.
McCreary 50
Mirror ..... 48 to 50, 54 to 58
Opal. See Opal Reflectors.
Prismatic. See Prismatic Reflectors.
Trough 54, 55, 326, 331
Use in art glass domes 169, 173
Balls 114
Bowls 108
Table lamps 167
X-ray 48, 56, 137
Refraction 7, 8
Residence Lighting ..... 151 to 214
Restaurant Lighting 236, 237, 240, 307
See also Dining-Room Lighting, Hotels.
Sand Blasted Balls 59
Reflectors 58, 139
Schedule of Fixtures 206
School Lighting 283, 284
Shop Lighting ..... 134, 332 to 336
Sleeping-car Lighting 291
Specifications for Lighting 207
Storage-room Lighting 26, 134
Store Lighting, by ..... 293 to 323
Electric arcs 296, 298, 301, 302, 307
Gas arcs ..... 297, 316 to 318
Gem lamps 296, 299, 322
Incandescent electric ..... 293 to 323
Mantle burners ..... 295, 319 to 321
Nernst lamps 296, 321
Open gas 294, 319
Store Lighting.
Color effects ..... 297 to 299
Store Lighting, Examples of
Automatic vaudeville 299
Bakery 316
Candy store 313, 319
Carpet store 300
Cigar store 315
Dry goods store 321, 322

PAGE.

Store Lighting, Examples of
Drug store 305, 321
Fur store 309
Furniture store 315
Grocery store 304
Hardware store 310
Hat store 313, 314
Jewelry store 308, 311
Meat store 302
Millinery store 318, 319
Picture store 316
Picture frame store 310
Railroad ticket office 302
Restaurant. See Restaurant Lighting.
Shoe store 301
Stationery store 306
Store Lighting, large vs. small units 295, 296
Streaks 11, 28, 34, 46, 48
Switch Control 149
Table Lamps. See Portable Lamps.
Tantalum Lamps 28, 143
Theatre Lighting, Auditorium ..... 262 to 267
Lobby ..... 246 to 248
Trough Reflectors 54, 55, 326, 331
Unsteady Light 9
Vapor Lamps. See Mercury Vapor Lamps.
Vertical Illumination 22
Warehouse Lighting 26, 134
Watts per square foot ..... 22 to 24, 226, 229, 251, 322, 336
Window Lighting ..... 39, 49, 55, 57, 94, 324 to 331
X-ray Reflectors 48, 56, 137

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